FDIBA in the New Technological World

Proceedings of the 11th FDIBA Conference
Sofia, Bulgaria, 26 November 2021

FDIBA in der Neuen Technologischen Welt

Tagungsband der 11. FDIBA Konferenz
Sofia, Bulgarien, 26. November 2021

Technische Universität Sofia
Karlsruher Institut für Technologie
Hochschule für Ökonomie und Management Essen
Technische Universität Braunschweig
Otto von Guericke Universität Magdeburg

With the financial support of the German Academic Exchange Service

DAAD

Deutscher Akademischer Austauschdienst
German Academic Exchange Service

Mit der Förderung des Deutschen Akademischen Austauschdienstes

Technical Program Committee

Chair: Marin Marinov

Mathias Kluwe
Stefan Stefanov
Hristomir Yordanov

Organisation Committee

Chair: Hristomir Yordanov

Yordan Yordanov
Marin Marinov
Daniel Kulesza

Reviewers

Ralitza Dimitrova
Zwetelina Gankova-Ivanova
Georgi Chankov Georgiev
Boris Kirov
Peter Lang
Marin Marinov
Stefan Stefanov
Aleksandar Tsenov
Hristomir Yordanov
Ralitsa Zayakova-Krushkova

Date: Friday, 26/Nov/2021

10:00 - 10:30

PLN: Plenary
Session Chair: **Dr. Hristomir Yordanov**

Tendecies in the management of modern communication and information systems
Aleksandar Tsenov (aleksandar.tsenov@fdiba.tu-sofia.bg)

10:30 - 11:30

ECO: Economics
Session Chair: **Prof. Peter Lang**
Session Chair: **Dr. Milena Yordanova Krumova**

Einige ökonomische Aspekte der Digitalisierung der Energetik
Zwetelina Gankova - Ivanova (zwetelina_gankova_7@yahoo.de)

Emotion-Reaction Guidelines for Service Interactions
Michael Meyer, Varinia Wittholz, Susanne Robra-Bissantz, (m.meyer@tu-braunschweig.de)

Squaring The Circle: Leading Companies in a Contradictory World
Hans-Paul Bürkner, Arindam Bhattacharay (buerkner.hans-paul@bcg.com)

11:30 - 12:10

LAW: Law
Session Chair: **Dr. Milena Yordanova Krumova**

Compliance Rules: Renaissance of "Neo-Protectionism"?
Malte Pehl (maltepehl@web.de)

International expansion of "Compliance"
Malte Pehl (maltepehl@web.de)

12:10 - 13:10

ENG: Engineering
Session Chair: **Dr. Hristomir Yordanov**

Customization and Update Mechanism for an Auction based Automotive Power Network Management
Tobias Schürmann (schuermann@fzi.de)

Explicit Port-Hamiltonian Representation of Feedthrough-Systems with Nonlinear Dissipation
Martin Pfeifer, Mathias Kluwe, Sören Hohmann (martin.pfeifer@kit.edu)

Preconditions for Ergonomic Working Places ´2021
Svetla Ivanova-Vassileva (vassileva@fdiba.tu-sofia.bg)

14:00 - 15:40

PhD: Doctoral Students
Session Chair: **Prof. Marin Marinov**

A concept to develop and operationalize a ranking of business process model metrics in the context of predictive process monitoring
Florian Spree (Florian.Spree@t-online.de)

Battery Energy Storage System – Benefits and Risks
Nikolay Kambosev (kambosev@gmail.com)

Claims of Priority Right
Dimitrina Stefanova (dimitrina.stefanova@gmail.com)

Droplet Formation Mechanism in Microfluidc Devices
Emil Grigorov (emil.rumenov.grigorov@abv.bg)

The right of priority in trademark registration - Is the Bulgarian legislation comprehensive?
Dimitrina Stefanova (dimitrina.stefanova@gmail.com)

THIS PAGE IS INTENTIONALLY LEFT BLANK

Contents

THIS PAGE IS INTENTIONALLY LEFT BLANK

Economics and Law

Chair: Peter Lang, Milena Krumova

This page is intentionally left blank

Some economic Aspects of the Energetic's Digitalization

Einige ökonomische Aspekte der Digitalisierung der Energetik

Zwetelina Gankova - Ivanova[*]

[*]Faculty of Economics, Technical University of Gabrovo
Gabrovo, Bulgaria, zwetelina_gankova_7@yahoo.de

Abstract — Die Aktualität der Forschungen im Bereich der Digitalisierung der Energetik wird dadurch bestimmt, dass die Digitalisierung als Prozess einer der vorrangigen Stränge in der Entwicklung der modernen Welt verstanden wird und für die stabile Entwicklung der Wirtschaft entscheidend ist. Ziel des vorliegenden Beitrages ist es, ein umfassendes Bild der Digitalisierung der Elektroenergetik und einiger ihrer wirtschaftlichen Aspekte zu vermitteln. Zu diesem Zweck werden solche Aufgaben gelöst, wie z. B. die Begründung der Notwendigkeit der Digitalisierung, das Hervorheben der Prioritäten der digitalen Energiewende und die Darstellung ihrer Erscheinungsformen und ihrer wirtschaftlichen Aspekte.

Zusammenfassung — The relevance of the research in the field of digitalization of energetic is determined by the fact that digitalization as a process is one of the priority strands in the development of the modern world and is crucial for the stable development of the economy. The purpose of this study is to give a comprehensive picture of the digitization of electricity and some of its economic aspects. To this end, such tasks are decided, such as justifying the need for digitisation, outlining the priorities of the digital transformation of energy and presenting the forms of its manifestation and its economic aspects *(Abstract)*

I. Einführung

Die Relevanz der Forschungen im Bereich der Digitalisierung der Energetik wird dadurch bestimmt, dass die Digitalisierung als Prozess einer der Prioritäten in der Entwicklung der modernen Welt ist und für die stabile Entwicklung der Wirtschaft entscheidend ist. Ziel dieser Studie ist es, ein umfassendes Bild der Digitalisierung der Elektroenergetik und einiger ihrer wirtschaftlichen Aspekte zu vermitteln. Zu diesem Zweck werden solche Probleme beleuchtet, wie z.B. die Begründung der Notwendigkeit der Digitalisierung, das Hervorgeben der Prioritäten der digitalen Energiewende und die Darstellung der Erscheinungsformen und ihrer wirtschaftlichen Aspekte.

Die Liberalisierung des Strommarktes und die Dezentralisierung der Stromerzeugung erfordern eine Umgestaltung der Verteilung und der Kontrolle in diesem Sektor. Dabei spielt die Digitalisierung eine führende Rolle. Die Transformation der Elektroenergetik ist die größte IT-Herausforderung aller Zeiten: Die digitale Transformation der Energiewirtschaft steht im Mittelpunkt dieses Prozesses. Immer mehr Stromversorger nutzen diesen Trend und bringen ihre Ideen in Digitalisierungsstrategien zusammen. In Bezug darauf stellt sich die Frage, wer sich in absehbarer Zeit auf dem Energiemarkt etablieren wird sowie wie und mit welchen Geschäftsmodellen dies stattfinden könnte.

Die bulgarische Energiewirtschaft ist ebenfalls von dieser Entwicklung betroffen. Die Anforderungen an ein sicheres und bezahlbares erneuerbares Energieversorgungssystem gewinnen im Zuge der Digitalisierung zusätzliche Dynamik und sollen neue Lösungen, Herausforderungen und Chancen generieren.

II. Wesen der Digitalisierung des elektroenergetischen Sektors

Die Digitalisierung der Elektroenergetik ist ein Element der Digitalisierung der ganzen Wirtschaft. Die Digitalisierung der Wirtschaft selbst stellt eine neue soziokulturelle ökonomische Realität dar und ist das Ergebnis der Implementierung und Weiterentwicklung von Informations- und Kommunikationstechnologien. [12], [13] Das Wesen der Digitalisierung der Elektroenergiewirtschaft bezieht sich auf die Schaffung von einer effizienten Informations- und Telekommunikations-infrastruktur, die die technologische Möglichkeit für die Anwendung des Internets in der Branche, Maßnahmen zur Verbesserung der rechtlichen und regulatorischen Dokumentation sowie neue Wege zur Personalbeschaffung und Informationsbereitstellung bietet. Im Mittelpunkt der Digitalisierung steht die Automatisierung, einschließlich der Implementierung intelligenter Strommessungen. Maßgebliche Voraussetzungen für die Digitalisierung der Elektroenergiewirtschaft weltweit sind die technologischen Innovationen, die wissenschaftlichen Entwicklungen in diesem Bereich, die Infrastrukturentwicklung und die Mechanismen zur Unterstützung des Innovationsgeschäfts.

Der Energiesektor steht kurz vor einer der bedeutendsten technologischen Transformationen seit 1880. Dann entdeckte die Firma Edison Electric Light das Geheimnis der Herstellung einer praktischen und erschwinglichen Glühbirne - mit einem Glühfaden aus verkohlten Spänen aus japanischem Bambus. In der Folge, nur innerhalb weniger Jahre, wurden Gaslampen für die Beleuchtung zu veralteten Technologien. Es wird erwartet, dass die neuen Geschäftsmodelle auf innovativen Technologien basieren, dazu gehören dezentrale Energietechnologien wie virtuelle Kraftwerke und Energiebatterien. Die sektorale Regulierung sollte auch im Hinblick auf die neuen

Technologien gelockert werden, d. h. Subventionierung von Strom aus erneuerbaren Quellen, Anforderungen an intelligente Messsysteme und Stromzähler.

Die umfangreiche Automatisierung und die erweiterten Analysen sollen die Grundlage für das Management wertbildender Prozesse werden. Mehrere Sensoren werden in automatisierten Produktionsanlagen installiert, von intelligenten Verteilnetzen bis hin zu Endgeräten und -diensten. Die Branchenführer werden damit beginnen, Erkenntnisse vom System als Ganzes bis zum spezifischen Verbraucher zu sammeln und dadurch werden sie "vertrauenswürdige Energieberater" und nicht nur Vermögensverwalter oder externe Lieferanten. All dies wird es ermöglichen, sicherzustellen, dass aufsichtliche Benchmarks erreicht und qualitativ hochwertige Dienstleistungen erbracht werden.

An dieser Stelle sind die Hauptprobleme näher zu behandeln, die im Zusammenhang mit der Digitalisierung der Energetik auftreten. Manche davon sind:

1. Steigerung der Marktdynamik: Hier ist es zu berücksichtigen, wie sich die Strompreise verändern werden und welche Volatilität erwartet wird; welche Strategie geeignet ist, um den sich ändernden Verbrauchererwartungen und der neuen demografischen Struktur Rechnung zu tragen; welche Elemente der zukünftigen Konsistenz der Wertschöpfung in der Branche für die Aktionäre von größtem Nutzen sein werden.

2. Einsatz neuer Technologien: In diesem Zusammenhang muss geklärt werden, wie der Übergang von einer zentralisierten zu einer dezentralen Struktur des Energiesektors erfolgen wird; welche organisatorischen und kulturellen Veränderungen die größtmögliche Wirkung der neuen Technologien gewährleisten werden; welche Strategie für den Einsatz neuer Technologien Vorteile gegenüber den Wettbewerbern ermöglichen wird (d. h. ob der Fokus auf die erneuerbaren Energien oder den elektrischen Verkehr zu richten ist).

3. Staatliche Regulierung des Sektors: Der Schwepunkt liegt darauf, welche Strategien im Falle einer strengeren Qualitätskontrolle der Anlagen und der Zuverlässigkeit der Stromnetze umzusetzen sind; was getan werden muss, um die Effizienz des Betriebs bei der Senkung der Tarife zu verbessern (Zugangskosten, Übertragungskosten); welche die Unterschiede in der Herangehensweise an die Unternehmensführung mit regulierten und unregulierten Tarifen (Preisen) sind.

III. PRIORITÄTEN DER DIGITALEN TRANSFORMATION IM ENERGETISCHEN SEKTOR

Bei der Umsetzung der digitalen Transformation im Energiesektor sollte in drei Bereichen gearbeitet werden:

1. Digitalisierung des aktuellen Betriebsmodells

In diesem Zusammenhang wird empfohlen, sich auf "Quick Wins" zu konzentrieren, d. h. Prozesse zu ermitteln, bei denen das größte Potenzial zur Kostensenkung und zur Verbesserung der Benutzerfreundlichkeit besteht. Zu den vorrangigen Bereichen können folgende Lösungen gehören: Automatisierung von Roboterprozessen, Digitalisierung interner Schnittstellen ("Joints") und der Nutzerinteraktion, Erhöhung der Datenverfügbarkeit und deren Einsatz für die Entscheidungsfindung, Digitalisierung von Personalmanagement-Tools, Aktualisierung der IT-Infrastruktur.

In der Stromverteilung sind die ersten Kandidaten für die digitale Transformation diejenigen Prozesse, die eine große Anzahl von sich wiederholenden Aktionen beinhalten: Anschluss neuer Verbraucher, Bedienung, Wartung und Instandhaltung des Netzwerks, Verwaltung von Investitionen, Gerätedaten, Verlusten.

2. Einsatz von erweiterten Analysen

Die Unternehmen im Stromsektor müssen einen Plan haben, um Daten aus verschiedenen Quellen zu "bereinigen" und sie zu standardisieren. Die Datenquellen und -modelle müssen miteinander verbunden werden, und der CDO (Chief Data Officer) und die zuständigen Mitarbeiter der Abteilungen sollen mit der Verantwortung für die Pflege der Erfassungs- und Speichersysteme innerhalb der Organisation beauftragt werden. Darüber hinaus ist es notwendig, die Kompetenz der Mitarbeiter bei der Verwendung fortschrittlicher Analysen zu erhöhen, da die Einführung von Technologien, z.B. "intelligenten" Zählern, die Datenmenge im Vergleich zur manuellen Erfassung erheblich erhöht und eine eingehende Analyse dieser Daten nicht mit Standard-Tools (z. B. Excel-Tabellen) durchgeführt werden kann.

3. Einführung neuer Technologien

Im Zusammenhang mit der Digitalisierung des Energiemanagements werden ein reichhaltiges Portfolio von Projekten sowie die Einführung von Pilotprojekten und die Verfolgung technologischer Entwicklungen, die Analyse von Kosten und Nutzen, die Bewertung der Bereitschaft für technologische Lösungen und deren Umsetzung in den industriellen Betrieb erwartet. Die Energieunternehmen sollten auch mit Unternehmen innerhalb des Finanzsektors, des E-Commerce und der Telekommunikation zusammenarbeiten, um ihr eigenes Portfolio an Produkten und Einkommensquellen zu erweitern. Kurzfristig zielen implementierte Technologien darauf ab, die Effizienz zu steigern und mittel- und langfristig die Kundenzufriedenheit zu erhöhen und neue Dienstleistungen anzubieten.

Die kurzfristigen Prioritäten in Bezug auf die digitale Energiewende lassen sich folgendermaßen definieren: Aufrechterhaltung des bestehenden Systems und Hinzufügen von Stromerzeugungskapazitäten; Fortsetzung der Asset-Management-Strategie auf Kosten großer Datenbanken und Zentralisierung der Fernwartung; Gewährleistung der Stabilität des Systems im Echtzeitmodus; Automatisierung und Digitalisierung von Prozessen; Implementierung von Nutzerinteraktionsplattformen und Einsatz prognostischer Analysen des Nutzerverhaltens; Angebot von Produkten für Smart-Häuser und Dienstleistungen für das Energiemanagement.

Die langfristigen Prioritäten, die festgelegt werden müssen, sind wie folgt: Gewährleistung einer optimalen Verteilung von Strom im Netz unter Berücksichtigung von Nachfrageänderungen; Nutzung großer Datenbanken und der analytischen Fähigkeiten von Supercomputern bei der Entscheidungsfindung; Implementierung von intellektuellen Energiesystemen und Gewährleistung der Möglichkeit, Feedback von den Nutzern zu erhalten; personalisiertes Kundenservice sowie zuverlässige Energieberatung; Angebot einer breiten Palette von Produkten für "intelligente" Häuser und Dienstleistungen für verschiedene Verbrauchergruppen und Schaffung langfristiger Beziehungen mit den Verbrauchern.

Ein Schlüsselfaktor für den Erfolg der Transformation der Energiewirtschaft ist die Bereitschaft von Organisationen und ihren Mitarbeitern, Digitalisierungstools zu beherrschen und die Vorteile der Digitalisierung zu nutzen, die Vorteile, die neue Technologien bieten.

IV. AUSPRÄGUNGSFORMEN DER DIGITALISIERUNG DES ENERGIESEKTORS

Die Energetik durchläuft derzeit eine doppelte Transformation: Neben der Energiewende verändert die

Digitalisierung die Grundlagen bestehender wertschöpfender Prozesse. Beide Entwicklungen sind direkt miteinander verbunden, da die Energiewende das weltweit größte IT-Projekt aller Zeiten ist. Die Integration von heute rund 1,5 Millionen Kraftwerken – meist dezentral und regenerativ – führt zu einer Komplexität, die nur mit Hilfe digitaler Systeme und modernster Infrastruktur realisiert werden kann. Der Ausbau der erneuerbaren Energien und der Komplexitätsgrad werden in der Zukunft weiter zunehmen. [7], [8], [9], [10] Kein anderer Industriezweig wird in der Zukunft mehr Datenbanken generieren, deren Bewertung eine sichere und effizientere Versorgung der Kunden ermöglichen wird. Gleichzeitig öffnen sich Perspektiven für neue Geschäftsfelder und für den internationalen Wettbewerb. Neben der Modernisierung der Hardware muss die Gesetzgebungssoftware sowohl auf nationaler, als auch auf europäischer Ebene aktualisiert werden. In diesem Zusammenhang sind Rechtssicherheit und Regeln für den Umgang mit Datenbanken erforderlich. Dazu braucht es innovationsfreundliche Rahmenbedingungen, die neue Geschäftsmodelle fördern und den Arbeitskräften von heute und morgen die notwendigen Qualifizierungsmöglichkeiten bieten. Generell führt dies zu einer Nachfrage nach einem technischen und unternehmerischen Betriebssystem für die Gesamtwirtschaft und für die Energetik. [1], [2], [3]

Veränderung im Wertschöpfungsprozess

Die Digitalisierung beschränkt sich nicht nur auf die "klassischen" Stufen und Grenzen im Prozess der Wertschöpfung. Obwohl sie alle Stufen der Wertschöpfungskette in unterschiedlichen Formen betrifft, umso mehr wird die Zerstörung der einst festen Grenzen des Systems und der technologischen Einschränkungen der Wertschöpfungsstufen intensiviert und fördert den Aufbau dynamischer Wertschöpfungsnetzwerke mit neuen Produkten und Geschäftsmodellen sowie mit neuen Wettbewerbern und Partnern außerhalb der eigenen Branche.

Digitales Unternehmen

Nicht nur der Energiesektor als Ganzes verändert sich, sondern jedes einzelne Unternehmen muss seine Anpassungsfähigkeit an den neuen Herausforderungen auf die Probe stellen. Eine erfolgreiche Digitalisierung im Unternehmen sollte sich nicht nur auf einen einzelnen Unternehmensbereich konzentrieren, sondern konsequent vom gesamten Unternehmen getragen werden. Dies erfordert Veränderungen in der Unternehmenskultur, der Führung, der Organisation, den (digitalen) Kompetenzen und in der Innovationsfähigkeit und nicht zuletzt unter anderem auch im konsequenten Change Management.

Kundenorientierung

Die Rolle von Haushalts- und Industriekunden im Energiesektor wandelt sich vom reinen Verbraucher zum aktiven Marktteilnehmer im Energiesystem. In einem neuen Marktumfeld, das von technischen und digitalen Innovationen sowie grundlegenden Veränderungen durch die Energiewende geprägt ist, ist es wichtig, die neuen Kundenbedürfnisse zu entschlüsseln und Produkte, Dienstleistungen und Geschäftsmodelle mit konstanter Unternehmensorientierung am Kunden zu schaffen. Die Erfahrungen der Kunden aus anderen Branchen, wo alles sofort, überall und günstig passiert, werden auch auf die Erwartungen der Kunden im Energiesektor übertragen.

IV. Verwirklichung der digitalen Transformation in der Energetik

Die digitale Transformation erfordert tiefgreifendere Veränderungen als nur ein einfaches Kostensenkungsprogramm, daher muss sie in die Unternehmensstrategie integriert werden und die richtige Aufmerksamkeit des Managements erhalten. Es ist wichtig zu bestimmen, welche die Schlüsselbereiche sind, welche Ressourcen das Unternehmen bereit ist, in jeden Bereich zu investieren und wie hoch der Umfang der Transformation sein sollte. Hauptsache ist, die Flexibilität zu bewahren und auf den Einsatz neuer Technologien schnell zu reagieren. Zum Beispiel war die Blockchain-Technologie bis vor kurzem mit Kryptowährungen verbunden und wird derzeit aktiv im Energiehandel, beim Informationsaustausch in Microgrids und zwischen Elektrofahrzeugen eingesetzt, um einen sicheren Zugang zu den Vermögenswerten und Informationen des Unternehmens zu gewährleisten. [5], [6], [11]

Bei der Schaffung einer "Roadmap" ist es für die Umsetzung zu berücksichtigen, dass schnelle Ergebnisse dazu beitragen können, die Organisation zu mobilisieren und einen reibungslosen Übergang von der Pilotphase zur vollständigen Umsetzung der Digitalisierung zu gewährleisten. Für den Übergang zur vollständigen Implementierung sollte ausreichend Zeit eingeplant werden - je nach gewählter Technologie zum Beispiel ein bis sechs Monate. In dieser Phase wird Zeit benötigt, um Pilotprogramme zu bewerten, das notwendige Know-how zu sammeln und die Ansichten der Marktpartner zu untersuchen, neue Betriebsmodelle zu entwickeln, die Aktivität zu standardisieren und zu bestimmen, welche Instrumente zur Kontrolle der Umsetzung und Bewertung der Ergebnisse erforderlich sind.

Die digitale Transformation betrifft alle Hierarchieebenen und alle Arten von Prozessen, daher muss die gesamte Organisation in ihr Implementierungsprogramm einbezogen werden. Pilotprogramme und -projekte sollten gleichzeitig gestartet werden, um die Verflechtung zwischen den Technologien zu verfolgen und potenzielle Synergien aufzuzeigen. Gleichzeitig sollten sich multidisziplinäre Teams auf Schnittstellen und die Beseitigung suboptimierter "Schwachstellen" konzentrieren. Die Funktion der Informations- und Kommunikationstechnologien (IKT) besteht darin, ein fester Bestandteil der digitalen Transformation zu sein und als strategischer Geschäftspartner zu agieren. Ein starkes IKT-Team bestimmt nicht nur das Tempo der Innovationsentwicklung im Unternehmen, sondern auch liefert Experteninformationen über die Technologien, die den Bedürfnissen des Unternehmens entsprechen.

Die Mitarbeiter vor Ort müssen mobile Personalmanagement-Tools beherrschen, die mit der erweiterten digitalen Realität (Augmented Digital Reality) kompatibel sind, sowie Online-Datenverarbeitungs- und Entscheidungsfindungstools. Um Veränderungen und neue Personalfunktionen zu managen, führen einige Unternehmen zusätzliche Hierarchieebenen von technisch qualifizierten Mitarbeitern ein.

Der Einsatz fortschrittlicher Analysetools erfordert kompetente Datenmanagement- und Kontrollexperten. Innovationsmanagement impliziert Positionen für digitale Projektmanager – Mitarbeiter in solchen Positionen werden als Innovationsleiter fungieren, andere schrittweise ermutigen, digitale Technologien zu nutzen und die Vorteile der Digitalisierung zu demonstrieren. [14], [15].

Die Energieunternehmen arbeiten zunehmend mit Start-ups und Technologieunternehmen zusammen, um gemeinsam neue Produkte zu entwickeln und die fortschrittlichsten Lösungen zu finden. Joint Ventures werden zu einer Möglichkeit, Zugang zu Know-how und Fähigkeiten zu erhalten, die in dieser Entwicklungsphase in der Organisation fehlen können. Sie arbeiten auch mit Kommunen zusammen, um Lösungen im Bereich des elektrischen Verkehrs und Smart Cities zu finden.

V. Schlussfolgerungen

Die Digitalisierung der Energetik führt zur „Auflösung" der bestehenden Grenzen zwischen verschiedenen Stufen wertbildender Prozesse, schafft neue Wettbewerber und Geschäftsmodelle und lässt Kunden und ihre individuellen Wünsche zum Gegenstand des Marktprozesses werden. Die Treibkräfte dieser Entwicklung sind: **Technologien:** Mit den neuen Internet-Anwendungen wie großen Datenbankanalysen oder Cloud- und mobilen Anwendungen können Energieunternehmen den spezifischen Digitalisierungsanforderungen in der Energiewirtschaft gerecht werden. So kann beispielsweise die zunehmende Zahl dezentraler Erzeugungsanlagen besser gesteuert und koordiniert werden. **Die Treibkräfte der Energiewirtschaft:** Die Energiewirtschaft unterliegt einem regulatorischen Rahmen. Neben der Energiewende und dem daraus resultierenden Bedürfnis nach mehr Flexibilität bedarf es neuerer gesetzlicher Regelungen, die die Sicherheit der Informationstechnologie und die Digitalisierung der Energiewende betreffen und eine entscheidende Rolle spielen, aber auch die Digitalisierung in der Energiewirtschaft nachhaltig beeinflussen. **Neue Geschäftsprozesse und -modelle:** Immer neuere und teilweise untypische Industrieunternehmen stoßen ständig auf die Strom-, Gas- und Wärmemärkte. Viele sind plattformbasiert und fungieren als Vermittler zwischen den Endkunden und den Energieversorgern. Das bedeutet eine deutliche Veränderung des bestehenden Geschäftsmodells der Energieversorger. **Kundenverbrauch und Lieferantendruck:** Der digitale Kunde erwartet einen neuen Ansatz im Energiebereich und hat andere Anforderungen an die Unternehmen. Die Unternehmen müssen darauf reagieren und Produkte und Angebote strikt an den Anforderungen des digitalen Kunden ausrichten.

Die Digitalisierung der Energetik führt die Unternehmen dazu, ihre internen Prozesse zu optimieren, zum Beispiel durch das sogenannte Process Mining. Die optimierten internen Prozesse sind ebenfalls erforderlich, um den sich ändernden Kundenbedürfnissen gerecht zu werden. Das elektrische Stromprodukt ist in der digitalisierten Welt dasselbe. Was sich beispielsweise ändert, sind die Vertriebskanäle, die dieses Produkt auf den Markt bringen und die Anforderungen der Kunden, denen es geliefert werden muss. Sie entwickeln sich von einfachen Verbrauchern zu immer aktiveren Marktteilnehmern im Energiesystem. Der digitale Kunde wünscht sich bequeme, personalisierte und sofort verfügbare Produkte. Auf der Vertriebsseite hat das beispielsweise den Effekt, dass die digitalen Multi-Channel-Plattformen ausgebaut werden. Auf diese Weise wollen die Unternehmen ihre Interaktion mit dem Kunden verknüpfen: online, mobil, im Callcenter und im Vor-Ort-Vertrieb. Gleichzeitig ermöglicht es die Analyse des Kundenverhaltens an allen Kontaktpunkten.

Die digitale Transformation erodiert auch die Grenzen der Wertschöpfung, zumindest wenn es im Energiesektor möglich ist. Die Daten kennen keine Grenzen und können gesammelt, verarbeitet und analysiert werden, damit Produkte und Dienstleistungen daraus generiert werden. Doch nicht nur die Grenzen wertschöpfender Prozesse verschwimmen im Zuge der Digitalisierung, sondern auch die Branchengrenzen erodieren und die Zusammenarbeit mit Neueinsteigern wird immer wichtiger. Darüber hinaus erfordert die Digitalisierung eine neue Kultur bei den Stromverteilern. Neue kollaborative Methoden oder die digitalen Kommunikationstechnologien spielen dabei eine zentrale Rolle. Grundsätzlich wirkt sich dies auf die Qualifikation der Mitarbeiter und die Bedingungen für ihre Einstellung aus. Die Frage, wie sich das ohnehin schon "schwer fassbare" Thema "Digitalisierung" entwickeln wird, wird die Energiewelt in den kommenden Jahren entscheiden. Führende Spezialisten auf dem Gebiet der Elektroenergetik behaupten, dass diese Transformation durch die Digitalisierung zu neuen Dynamiken führen wird.

References

[1] Albersmann, Joachim, Günter Dütsch, Martin, Jule, Theile, Hannes, Erken, Emre und Kern Dominik, "Die digitalisierte dezentrale Energieversorgung von morgen gestalten", Herausgegeben von der Pricewaterhouse Coopers GmbH Wirtschaftsprüfungsgesellschaft, 2017

[2] Die Digitale Energiewirtschaft. Agenda für Unternehmen und Politik, Hrsg. BDEW Bundesverband bei Energie- und Wasserwirtschaft e.V., Berlin, 2016

[3] Digitale Energieunternehmen. Energiewirtschaft 2020. White Paper zur Zukunft der Energiebranche, *www.managementcircle.de*

[4] Digitalization Survey Bulgaria, AHK, Deutsch Bulgarische Industrie- und Handelskammer, Sofia, 2018

[5] Dobes, G.M., Mezerhoff, J., Liebe, U., Erneuerbare Energien und Landschaftswandel. Einstellungen und Präferenzen zum Ausbau erneuerbarer Energien in Ökologisches Wirtschaften, 1.2015.

[6] Energiewirtschaft 20202. White Paper zur Zukunft der Energiebranche, Management Circle AG, 2020

[7] Ivanov, Krasimir M., Dieter Metz: Die Liberalisierung des Energiemarktes Bulgariens und die Rolle der SCADA Systeme für das Trainieren der Netzregime des Elektroenergiesystems (auf Bulgarisch: Liberalisazijata na energijnija pazar i mjastoto na sistemite SCADA sa trenirane na rejimite na mrejite na elektroenergijnata sistema), Internationale wissenschaftliche Konferenz UNITECH'04, Gabrovo, 18.-19. November 2004, Proceedings, Vol.I. P.I-66-72

[8] Ivanov, Krasimir M., Ivan Jotov: Die Untersuchung des Elektronergienetzes 20 kV mit dezentralen Einspeisungen, Internationale wissenschaftliche Konferenz UNITECH'15, Gabrovo, 20.-23. November 2015, Proceedings, Vol.I. P.I-154-159 (auf Bulgarisch: Iysledvane na mreji 20 kV s razpredelena generayija)

[9] Ivanov, Krasimir M., Z.K. Vyrbov, Untersuchung des Mittelspannungsnetzes mit angeschlossenen Kraftwerken erneubarer Energiequellen (auf Bulgarisch: Iysledvane na mreji na sredno naprejenie s priszedineni zentrali ot vzyobnovjaemi energoeistotchnizi), IV Wissenschaftliche Konferenz, EF2012 – Tage der Wissenschaft, Sofia, Sozopol, 28.September – 1. Oktober 2012, Vol. II., 2012, S. 388 – 397

[10] Ivanov, Krasimir Marinov, Tsviatko Kolev Varbov, Georgi Tsonev Velev: Calculation of losses of active power and energy in transmission lines and transformers, as a part of the electrical distribution power network, *Environment. Technology. Resources, Rezekne, Latvia, Proceedings of the 11th International Scientific and Practical Conference 2017 Volume III, 107-110*

[11] Künstliche Intelligenz für die Energiewirtschaft, Hrsg. BDEW Bundesverband bei Energie- und Wasserwirtschaft e.V., Berlin, 2020

[12] Lang, Franz Peter (2019). Quo vadis Digitale Revolution? Eine gesamtwirtschaftliche Analyse von Auswirkungen der Digitalisierung. In: Hermeier, B.; Heupel, T.; Fichtner-Rosada, S. (Hrsg.). Arbeitswelten der Zukunft, ISSN 2625-7114 FOM-Edition ISBN 978-3-658-23396-9, S. 3 - 22.

[13] Lang, Franz Peter, Digitization is changing our world, in: ISSN 1727-9313. ВІСНИК КНТЕУ. 2019. № 4, DOI: http://doi.org/10.31617/visnik.knute.2019(126)07, p. 74-84

[14] Papazov, E. & Mihaylova, L. (2019),Strategic Groups: Identification Techniques for Entrepreneurial Medium-Sized Enterprises, Ch. 13, pp. 287-311. In: Vemic, M. (Ed.). Strategic Optimization of Medium-Sized Enterprises in the Global Market, IGI-Global, Hershey, Pennsylvania.

[15] Petrova, S., *Isledvane vlijanieto na asortimentnija systav vyrhu potrebitelksiya izbor, in:* "Rasvitie na bylgarskata i evropejskata ikonomika – predisvikatelstva i vysmojnosti: Sbornik s nauchni izsledvanija ot godishna konferenzija na Stopanski fakultet na VTU „Sv.Sv. Kiril i Metodij", Veliko Tyrnovo, 17-18 oktomvri 2019, S. 61-67.

[16] Roth, Ines, Digitalisierung in der Energiewirtschaft. Technologische Trends und ihre Auswirkungen auf Arbeit und Qualifizierung, Working Paper Forschungsförderung, Nummer 073, Mai 2028, Hans Böckler Stiftung

Emotion-Reaction Guidelines for Service Interactions

Emotions-Reaktions-Guidelines für Serviceinteraktionen

Michael Meyer, Varinia Wittholz, Susanne Robra-Bissantz

Technische Universität Braunschweig, Institut für Wirtschaftsinformatik, Abteilung Informationsmanagement
Braunschweig, Germany, {m.meyer, l.wittholz, s.robra-bissantz}@tu-braunschweig.de

Abstract — The digital transformation and the effects of the COVID-19 pandemic are creating a critical situation for stationary retail. Emotions are highly relevant in this service context and represent an important part of the service experience. In particular, the ability of service personnel to understand and react to the emotions of customers is crucial to the success of service interactions. The goal of this paper is to design emotion-based guidelines for service personnel. These emotion-reaction guidelines (ERG) are intended to provide service personnel with specific options for adapting interactions to the emotional situation of customers. Based on a literature review, expert interviews and a digital workshop, ERG for six different customer emotions were designed, rated and summarized in the form of a digital whiteboard.

Zusammenfassung — Die digitale Transformation und die Auswirkungen der COVID-19-Pandemie schaffen eine kritische Situation für den stationären Handel. Emotionen sind in diesem Servicekontext von hoher Relevanz und stellen einen wichtigen Teil des Serviceerlebnisses dar. Insbesondere die Fähigkeit des Servicepersonals, die Emotionen der Kund:innen zu verstehen und korrekt auf diese zu reagieren, ist entscheidend für den Erfolg von Serviceinteraktionen. Ziel dieses Beitrags ist es, emotionsbasierte Handlungsempfehlungen für das Servicepersonal zu gestalten. Diese Emotions-Reaktions-Guidelines (ERG) sollen dem Servicepersonal konkrete Möglichkeiten bieten, Interaktionen an die emotionale Situation der Kund:innen anzupassen. Basierend auf einer Literaturrecherche, Experteninterviews und einem digitalen Workshop wurden ERG für sechs verschiedene Kund:innenemotionen entworfen, bewertet und auf einem digitalen Whiteboard zusammengefasst.

I. Introduction

Stationary retail is a domain suffering from both digital transformation and the impact of the COVID-19 pandemic. This situation makes it essential for retailers to design innovative services to meet the new challenges [1]–[4].

The unique characteristics of stationary retail lie in the qualifications of the service personnel, the resulting services and, in particular, the possibility of personal interaction between customers and service personnel [5]–[7]. A promising approach can therefore be to strengthen the service interaction (interaction between customers and service personnel) and thereby to support stationary retail.

Emotions are highly relevant in the service context and represent an important part of the service experience [5], [8]. Especially the ability of service personnel to understand and react to the emotions of the customer, is crucial to the success of service interactions [9]–[11]. An empathetic service interaction offers the opportunity to improve the service experience and build sustainable customer relationships [12], [13].

The goal of this paper is to design emotion-based guidelines for service personnel. These emotion-reaction guidelines (ERG) are intended to provide service personnel with specific options for adapting service interactions to the emotional situation of the customer. The ERG are based on a literature review as well as expert interviews with customers and service personnel [14], [15]. In addition to the actual design of the ERG, these were evaluated and rated in several workshops with potential customers. Finally, the evaluated ERG were summarized and illustrated in the form of a digital whiteboard.

This article is structured as follows. First, the current situation of stationary retailing is described. Subsequently, the relevance of emotions in the context of service design and especially service interaction is explained. Finally, the design of the ERG is outlined and its illustration in the digital whiteboard is presented. The article ends with a conclusion and an outlook, in which digital support possibilities for the ERG are discussed in particular [16].

II. Digital Transformation in Stationary Retail

The digital transformation and the effects of the COVID-19 pandemic are creating a critical situation for stationary retail. In particular, the growth of online retailing and the possibility of mobile shopping via smart devices are creating new challenges [2], [4]. In this context, declining customer frequency and stagnating sales show up as consequences of a change in the behavior of customers [17]. This situation is supported by the fact that 67% of Millennials and 56% of Gen-Xers prefer to shop online [18]. Modern customers are better informed and expect a personalized service experience [19], [20]. Smartphones enable customers to access the Internet regardless of time and place, which leads to a change in customer behavior as well as customer expectations [2], [21].

Although some retailers are able to retain their customers through multi-channel strategies, so-called Internet pure players account for a large share of (online) commerce, with Amazon alone accounting for a large share of online sales [19], [22].

The possibility of personal interaction between customers and service personnel represent a unique feature of stationary retail [5]–[7]. From the customer's perspective, this (service) interaction can be representative of the perception of the entire service [23]–[25]. A service interaction creates a connection between the service personnel and the customer, which can be the basis for mutual value creation [26], [27].

The currently predominant COVID-19 pandemic intensifies the critical situation for stationary retail, not only because stores are oftentimes temporarily closed but because the sales personnel has difficulties to fully recognize the customer's emotions displayed by facial expressions due to facemasks [28], [29]. In a situation in which the stationary retail is reliant on offering customers good service, this can lead to inappropriate responses. Empathy, care and concern are especially important for ensuring appropriate interactions in these challenging times [30].

III. EMOTIONS IN SERVICE INTERACTIONS

Emotions influence how people behave, think, communicate and interact [8], [31], [32]. An emotion is the reaction of the human body to an occurring stimulus, e.g. to an event or a thought of certain relevance [8]. Emotions lead to high mental activities and are perceived as positive or negative [31].

Customer perception of stationary retail is strongly influenced by emotions. Both the design of the store and the interaction between service personnel and the customer have an effect on the emotional situation of the customer [5], [33]. The emotional situation of the customer thus forms an important part of the service experience and has an impact on customer behavior, perceived service quality, customer satisfaction and customer loyalty [5], [8], [34], [35].

The behavior and abilities of the service personnel play a critical role in service design, as they can have a significant impact on customer experiences and perceptions [11], [23], [25], [36]. In this context, the way of service interaction can influence the perceived service quality, customer satisfaction and the emotional situation of the customer [10], [11], [23], [25].

An important aspect of successful service interactions and customer satisfaction is the ability of service personnel to understand and react appropriately to the emotional situation of the customer [9]–[11].

Recognizing and reacting to emotions can be challenging without specific training, and even experienced service personnel may have difficulties in correctly perceiving customer emotions [11], [16]. For example, the assessment of customer emotions by the service personnel does not always correspond to those of the customers [11], [37]. Negative emotions are particularly relevant, as they can have a much stronger influence on customers than positive emotions [38]. Negative emotions can have a negative impact on customer satisfaction and loyalty, leading to damaging word-of-mouth [12], [38]–[41]. Customers with positive emotions, on the other hand, show higher satisfaction and improved loyalty [5].

IV. EMOTION-REACTIONS GUIDELINES

The aim of this paper is the design and evaluation of ERG, which are intended to provide service personnel with specific options to react correctly to the emotional situation of the customer.

Design of the ERG

Based on a literature review and expert interviews with service personnel in stationary retail, a total of 117 specific ERG and 30 general ERG were designed. In the course of the literature review, primarily service, retail and marketing literature was used and evaluated [37], [42], [15].

In this context, ERG could be identified for a total of nine different emotional situations, which were categorized according to the Circumplex Model of Affect for better clarity. The Circumplex Model of Affect is one of the most cited emotion models and represents emotions using the two dimensions *arousal* (activated vs. deactivated) and *pleasure* (positive vs. negative). The model is able to represent any emotional situation in terms of a certain degree of these two dimensions. For example, the emotion *happy* arises from the combination of a high activation (*arousal*) and a pleasant sensation (*pleasure*). In this way, a multitude of emotions can be intuitively arranged in a two-dimensional space [8], [43].

Using the dimensions presented, four quadrants (Q1 to Q4) can be distinguished within the model [16]. **Q1:** negative activated – *angry/frustrated, embarrassed, afraid,* **Q2:** positive activated – *interested, happy/excited,* **Q3:** negative deactivated – *sad/tired, bored,* **Q4:** positive deactivated – *relieved, relaxed/satisfied* (see Figure 1).
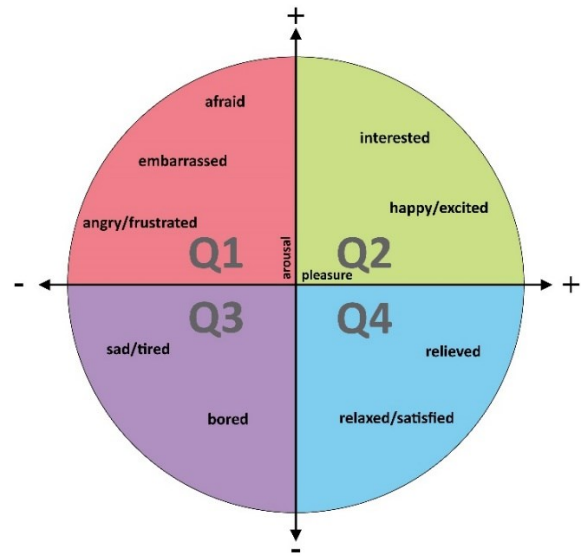

Figure 1: Circumplex Model of Affect

Evaluation of the ERG

For the evaluation of the ERG, six digital workshops with a total of 24 participants were conducted (four participants per workshop). The age of the participants ranges from 22 to 32 years, with an average age of 24.75 years. 62.5% of the participants are male and 37.5% are female. All participants stated that they regularly shop in stationary retail stores.

The workshops were realized using the digital collaborative whiteboard platform *Miro* in combination with the telecommunications and videoconferencing app *Skype*.

The integrated voting tool in *Miro* was used to evaluate the ERG. For each emotional situation the participants could favor three ERG. Furthermore, ERG could be rated as **1:** *inappropriate*, **2:** *general and valid for any emotion* or **3:** *belonging to another emotion*. Also, ERG were considered as *inconspicuous* if they have been evaluated by fewer than 8 participants.

In addition to the ERG favored for each emotion, three main results emerged from the workshops: **I:** The allocation of the ERG from the literature review to the respective emotional situation was perceived as appropriate by the participants. Thus, the ERG offer meaningful and appropriate guidelines for the respective emotional situations. **II:** For the emotional situation *angry/frustrated*, two ERG were found to be *inappropriate*: *"treat the customer with humor"* and *"show submissive behavior"*. According to the participants the former is due to the

fact that it is difficult to meet a person's sense of humor. The latter is related to the fact that the service personnel should keep their own dignity and not put up with everything the customer does. The identification of this ERG is of great importance in terms of the emotional strain that service personnel may face as a result of emotional labor [44], [45].

III: Some of the ERG that are directly associated with an emotional situation were evaluated as *general and valid for any emotion*. These ERG were grouped together as *general ERG*.

Summary and Illustration of the ERG

The results of the research and the workshop were finally summarized in a digital whiteboard which can be viewed following this link: https://miro.com/app/board/o9J_lrDIn6s=/

The basic structure of the digital whiteboard is based on the four quadrants presented and the nine different emotional situations in terms of color and content (see Figure 1). The upper part of the digital whiteboard summarizes the results of the literature review and expert interviews (see Digital Whiteboard: Section A). In the lower part of the digital whiteboard the results of the workshops can be found (see Digital Whiteboard: Section B). The literature used for the ERG can be found on the right side of the digital whiteboard (see Digital Whiteboard: Section C).

The best-rated ERG can also be found in Table 1.

TABLE I.   BEST-RATED ERG

negative Emotions	
Emotion	**ERG**
general negative emotions	• offer help [46]
embarrassed	• take the customer seriously [47], [48]
angry/frustrated	• leave customers alone who want to be left alone [49]
afraid	• open body language, respectful and polite interaction [37], [48], [50]–[53]
sad/tired	• open, interested, honest and appreciative behavior towards the customer [51], [53]
bored	• show the customer something new about the product or lead him/her into new areas of the store [53]–[56]
positive Emotions	
Emotion	**ERG**
general positive emotions	• show authentic, positive emotions; empathic and authentic behavior [57], [58]
happy/excited	• show positive emotions and mirror positive behavior [14], [15], [37], [58]
interested	• interaction and communication through polite support and kind words [14], [15]
relaxed/satisfied	• friendly and efficient interaction [59], [60]
relieved	• show calmness and competence [14], [15]

CONCLUSION AND OUTLOOK

With the overarching goal of supporting stationary retail in the digital transformation, this paper focused on its existing strengths: the interaction between customer and service personnel. An important aspect of successful service interaction and customer satisfaction is the ability of service personnel to understand and react appropriately to the emotional situation of the customer [9]–[11]. The emotional situation of the customer forms an important part of the service experience and has an impact on customer behavior, perceived service quality, customer satisfaction and customer loyalty [5], [8], [34], [35].

To ensure that the customer has a pleasant and valuable visit, we designed und rated a high number of ERG for different emotional situations. These ERG are intended to provide service personnel with specific options for adapting interactions to the emotional situation of the customer. By presenting the ERG as a digital whiteboard, easy access (also outside the scientific community) is provided. The digital whiteboard also offers the opportunity to collect further opinions on the ERG or completely new ERG via the comment function.

A limitation of this contribution is that it deals exclusively with the reaction to emotions. In view of the fact that recognizing customer emotions can also be challenging, service personnel should likewise be supported in this area. One possibility to support service personnel in recognizing emotions is offered by digital emotion-self-assessment interfaces [61]. In addition, it could be valuable to support the ERG more strongly with IT by implementing it in the form of a mobile application. In this way, the management and specific selection of the ERG could also be ensured directly in the service environment [16]. Furthermore, service interactions also take place in other branches, such as restaurants or hotels. These branches represent a promising source for the development of further ERG.

REFERENCES

[1] N. F. Doherty and F. Ellis-Chadwick, "Evaluating the role of electronic commerce in transforming the retail sector," *Int. Rev. Retail Distrib. Consum. Res.*, vol. 20, no. 4, pp. 375–378, Sep. 2010, doi: 10.1080/09593969.2010.504001.

[2] G. M. Fulgoni, "The Rise of the Digital Omnivore: What It Means for Advertisers, Publishers, and App Developers," *J. Advert. Res.*, vol. 55, no. 2, pp. 115–119, Jun. 2015, doi: 10.2501/JAR-55-2-115-119.

[3] M. Geiger, F. Jago, and S. Robra-Bissantz, "Physical vs. Digital Interactions: Value Generation Within Customer-Retailer Interaction," in *Proceedings of 34rd Bled eConference Digital Support from Crisis to Progressive Change*, Bled, Slovenia, 2021, pp. 153–166. doi: https://doi.org/10.18690/978-961-286-385-9.

[4] W. Reinartz, N. Wiegand, and M. Imschloss, "The impact of digital transformation on the retailing value chain," *Int. J. Res. Mark.*, vol. 36, no. 3, pp. 350–366, Sep. 2019, doi: 10.1016/j.ijresmar.2018.12.002.

[5] D. J. Burns and L. Neisner, "Customer satisfaction in a retail setting: The contribution of emotion," *Int. J. Retail Distrib. Manag.*, vol. 34, no. 1, pp. 49–66, Jan. 2006, doi: 10.1108/09590550610642819.

[6] B. A. Gutek, A. D. Bhappu, M. A. Liao-Troth, and B. Cherry, "Distinguishing between service relationships and encounters.," *J. Appl. Psychol.*, vol. 84, no. 2, pp. 218–233, 1999, doi: 10.1037/0021-9010.84.2.218.

[7] J. R. Otto and Q. B. Chung, "A Framework for Cyber-Enhanced Retailing: Integrating E-Commerce Retailing with Brick-and-Mortar Retailing," *Electron. Mark.*, vol. 10, no. 3, pp. 185–191, Jul. 2000, doi: 10.1080/10196780050177099.

[8] R. P. Bagozzi, M. Gopinath, and P. U. Nyer, "The Role of Emotions in Marketing," *J. Acad. Mark. Sci.*, vol. 27, no. 2, pp. 184–206, Apr. 1999, doi: 10.1177/0092070399272005.

[9] W. Bahadur, S. Aziz, and S. Zulfiqar, "Effect of employee empathy on customer satisfaction and loyalty during employee–customer interactions: The mediating role of customer affective commitment and perceived service quality," *Cogent Bus. Manag.*, vol. 5, pp. 1–21, Jul. 2018, doi: https://doi.org/10.1080/23311975.2018.1491780.

[10] M. J. Bitner, B. H. Booms, and L. A. Mohr, "Critical Service Encounters: The Employee's Viewpoint," *J. Mark.*, vol. 58, no. 4, pp. 95–106, 1994, doi: 10.2307/1251919.

[11] A. S. Mattila and C. A. Enz, "The Role of Emotions in Service Encounters," *J. Serv. Res.*, vol. 4, no. 4, pp. 268–277, May 2002, doi: 10.1177/1094670502004004004.

[12] A. Heyes and S. Kapur, "Angry customers, e-word-of-mouth and incentives for quality provision," *J. Econ. Behav. Organ.*, vol. 84, no. 3, pp. 813–828, Dec. 2012, doi: 10.1016/j.jebo.2012.10.002.

[13] S. S. Hussain, C. Peter, and G. Bieber, "Emotion Recognition on the Go: Providing Personalized Services based on Emotional State," in *Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services*, Bonn Germany, 2009, pp. 1–4.

[14] M. Meyer and S. Robra-Bissantz, "The Right Reaction: Entwicklung und Evaluation eines emotionsbasierten Software-Prototypen," in *Gemeinschaften in Neuen Medien. Von hybriden Realitäten zu hybriden Gemeinschaften*, Dresden, 2020, pp. 99–109.

[15] M. Meyer, P. Helmholz, F. Temps, and S. Robra-Bissantz, "(How) Can I help you? Emotion-Reaction-Guidelines for the Stationary Retail," in *Proceedings of the 9th FDIBA Conference: Challenges of the Digital World*, Sofia, Bulgaria, 2019, vol. 3, pp. 89–92.

[16] M. Meyer, D. Siemon, and S. Robra-Bissantz, "Emotion-based IS support for Customer-Salesperson Interaction," in *Proceedings of the 54th Hawaii International Conference on System Sciences*, Jan. 2021, pp. 4426–4435. doi: 10.24251/HICSS.2021.538.

[17] Handelsverband Deutschland, "HDE-Zahlenspiegel 2020," Handelsverband Deutschland (HDE), 2020. Accessed: Jul. 07, 2021. [Online]. Available: https://einzelhandel.de/publikationen-hde/zahlenspiegel

[18] BigCommerce, "U.S. online shopping preference by age group," *Statista*, 2017. https://www.statista.com/statistics/242512/online-retail-visitors-in-the-us-by-age-group/ (accessed Feb. 23, 2020).

[19] J. Hagberg, M. Sundstrom, and N. Egels-Zandén, "The digitalization of retailing: an exploratory framework," *Int. J. Retail Distrib. Manag.*, vol. 44, no. 7, pp. 694–712, Jul. 2016, doi: 10.1108/IJRDM-09-2015-0140.

[20] L.-B. Oh and H.-H. Teo, "Consumer Value Co-creation in a Hybrid Commerce Service-Delivery System," *Int. J. Electron. Commer.*, vol. 14, no. 3, pp. 35–62, Apr. 2010, doi: 10.2753/JEC1086-4415140303.

[21] B. I. Spaid and D. J. Flint, "The Meaning of Shopping Experiences Augmented By Mobile Internet Devices," *J. Mark. Theory Pract.*, vol. 22, no. 1, pp. 73–90, Jan. 2014, doi: 10.2753/MTP1069-6679220105.

[22] Handelsverband Deutschland, "HDE-Online Monitor 2021," Handelsverband Deutschland (HDE), 2021. Accessed: Sep. 07, 2021. [Online]. Available: https://einzelhandel.de/online-monitor

[23] M. J. Bitner, B. H. Booms, and M. S. Tetreault, "The Service Encounter: Diagnosing Favorable and Unfavorable Incidents," *J. Mark.*, vol. 54, no. 1, pp. 71–84, 1990, doi: 10.2307/1252174.

[24] S. Lee and A. Dubinsky, "Influence of salesperson characteristics and customer emotion on retail dyadic relationships," *Int. Rev. Retail Distrib. Consum. Res.*, vol. 13, no. 1, pp. 21–36, Jan. 2003, doi: 10.1080/09593960321000051666.

[25] M. R. Solomon, C. Surprenant, J. A. Czepiel, and E. G. Gutman, "A Role Theory Perspective on Dyadic Interactions: The Service Encounter," *J. Mark.*, vol. 49, no. 1, pp. 99–111, 1985, doi: 10.2307/1251180.

[26] A. Fyrberg and R. Jüriado, "What about interaction?: Networks and brands as integrators within service-dominant logic," *J. Serv. Manag.*, vol. 20, no. 4, pp. 420–432, Aug. 2009, doi: 10.1108/09564230910978511.

[27] C. Grönroos, "Adopting a service logic for marketing," *Mark. Theory*, vol. 6, no. 3, pp. 317–333, Sep. 2006, doi: 10.1177/1470593106066794.

[28] R. Adolphs, "Cognitive neuroscience of human social behaviour," *Nat. Rev. Neurosci.*, vol. 4, no. 3, pp. 165–178, Mar. 2003, doi: 10.1038/nrn1056.

[29] C.-C. Carbon, "Wearing Face Masks Strongly Confuses Counterparts in Reading Emotions," *Front. Psychol.*, vol. 11, 2020, doi: 10.3389/fpsyg.2020.566886.

[30] R. Diebner, E. Silliman, K. Ungerman, and M. Vancauwenberghe, "Adapting customer experience in the time of coronavirus," 2020. http://ceros.mckinsey.com/coronavirus-promo (accessed Feb. 16, 2021).

[31] M. Cabanac, "What is emotion?," *Behav. Processes*, vol. 60, no. 2, pp. 69–83, Nov. 2002, doi: https://doi.org/10.1016/S0376-6357(02)00078-5.

[32] J. Gratch and S. Marsella, "A domain-independent framework for modeling emotion," *Cogn. Syst. Res.*, vol. 5, no. 4, pp. 269–306, Dec. 2004, doi: 10.1016/j.cogsys.2004.02.002.

[33] R. Donovan, "Store atmosphere and purchasing behavior," *J. Retail.*, vol. 70, no. 3, pp. 283–294, 1994, doi: 10.1016/0022-4359(94)90037-X.

[34] D. Martin, M. O'Neill, S. Hubbard, and A. Palmer, "The role of emotion in explaining consumer satisfaction and future behavioural intention," *J. Serv. Mark.*, vol. 22, no. 3, pp. 224–236, 2008, doi: 10.1108/08876040810871183.

[35] G. Tumbat, "Co-constructing the service experience: Exploring the role of customer emotion management," *Mark. Theory*, vol. 11, no. 2, pp. 187–206, Jun. 2011, doi: 10.1177/1470593111403219.

[36] P. C. Verhoef, K. N. Lemon, A. Parasuraman, A. Roggeveen, M. Tsiros, and L. A. Schlesinger, "Customer Experience Creation: Determinants, Dynamics and Management Strategies," *J. Retail.*, vol. 85, no. 1, pp. 31–41, Mar. 2009, doi: 10.1016/j.jretai.2008.11.001.

[37] K. Menon and L. Dubé, "Ensuring greater satisfaction by engineering salesperson response to customer emotions," *J. Retail.*, vol. 76, no. 3, pp. 285–307, Jul. 2000, doi: 10.1016/S0022-4359(00)00034-8.

[38] T. Strandvik and V. Liljander, "Emotions in service satisfaction," *Int. J. Serv. Ind. Manag.*, vol. 8, no. 2, pp. 148–169, May 1997, doi: 10.1108/09564239710166272.

[39] K. Gelbrich, "Anger, frustration, and helplessness after service failure: coping strategies and effective informational support," *J. Acad. Mark. Sci.*, vol. 38, no. 5, pp. 567–585, Oct. 2010, doi: 10.1007/s11747-009-0169-6.

[40] J. R. McColl-Kennedy and A. K. Smith, "Customer Emotions in Service Failure and Recovery Encounters," *Res. Emot. Organ.*, p. 45, 2006.

[41] Y.-C. Ou and P. C. Verhoef, "The impact of positive and negative emotions on loyalty intentions and their interactions with customer equity drivers," *J. Bus. Res.*, vol. 80, pp. 106–115, Nov. 2017, doi: 10.1016/j.jbusres.2017.07.011.

[42] A.-M. Kranzbühler, A. Zerres, M. H. P. Kleijnen, and P. W. J. Verlegh, "Beyond valence: a meta-analysis of discrete emotions in firm-customer encounters," *J. Acad. Mark. Sci.*, vol. 48, no. 3, pp. 478–498, May 2020, doi: 10.1007/s11747-019-00707-0.

[43] J. A. Russell, "A circumplex model of affect," *J. Pers. Soc. Psychol.*, vol. 39, no. 6, pp. 1161–1178, 1980, doi: 10.1037/h0077714.

[44] B. E. Ashforth and R. H. Humphrey, "Emotional Labor in Service Roles: The Influence of Identity," *Acad. Manage. Rev.*, vol. 18, no. 1, pp. 88–115, Jan. 1993, doi: 10.5465/amr.1993.3997508.

[45] A. A. Grandey, "Emotional regulation in the workplace: A new way to conceptualize emotional labor.," *J. Occup. Health Psychol.*, vol. 5, no. 1, pp. 95–110, 2000, doi: 10.1037/1076-8998.5.1.95.

[46] J.-J. Wu and S.-T. Chang, "Exploring customer sentiment regarding online retail services: A topic-based approach," *J. Retail. Consum. Serv.*, vol. 55, 2020, doi: 10.1016/j.jretconser.2020.102145.

[47] C. Goodwin and I. Ross, "Consumer Evaluations of Responses to Complaints: What's Fair and Why," *J. Consum. Mark.*, vol. 7, no. 2, pp. 39–47, Jan. 1990, doi: 10.1108/EUM0000000002575.

[48] T. Gruber, "I want to believe they really care: How complaining customers want to be treated by frontline employees," *J. Serv. Manag.*, vol. 22, no. 1, pp. 85–110, Jan. 2011, doi: 10.1108/09564231111106938.

[49] M. Meyer and T. Strohmann, "Ich fühle mit dir! Können empathische virtuelle Assistenten den stationären Einzelhandel unterstützen?," *HMD Prax. Wirtsch.*, Dec. 2018, doi: 10.1365/s40702-018-00479-1.

[50] B. Parkinson and P. Totterdell, "Classifying Affect-regulation Strategies," *Cogn. Emot.*, vol. 13, no. 3, pp. 277–303, May 1999, doi: 10.1080/026999399379285.

[51] K. Niven, P. Totterdell, and D. Holman, "A classification of controlled interpersonal affect regulation strategies.," *Emotion*, vol. 9, no. 4, pp. 498–509, 2009, doi: 10.1037/a0015962.

[52] C. Hellbach, "Kriterien gelungener Emotionsarbeit im persönlichen Verkauf : am Beispiel Augenoptiker," Dissertation, Bayreuth, 2016. Accessed: Dec. 10, 2020. [Online]. Available: https://epub.uni-bayreuth.de/2702/

[53] S. Niedermeier and N. Schaper, "Die Rolle der emotionalen Kompetenz von Coaches im Coachingprozess," *Coach. Theor. Prax.*, vol. 3, no. 1, pp. 47–64, Dec. 2017, doi: 10.1365/s40896-017-0019-3.

[54] W. Kroeber-Riel and A. Gröppel-Klein, *Konsumentenverhalten*, 10., Überarbeitete, Aktualisierte und ergänzte Auflage. München : Verlag Franz Vahlen, 2013.

[55] P. J. Haynes, "Hating to Wait: Managing the Final Service Encounter," *J. Serv. Mark.*, vol. 4, no. 4, pp. 20–26, Jan. 1990, doi: 10.1108/EUM0000000002522.

[56] T. Foscht, B. Swoboda, and H. Schramm-Klein, *Käuferverhalten: Grundlagen - Perspektiven - Anwendungen*, 6., Aktualisierte Auflage. Wiesbaden: Springer Gabler, 2017.

[57] M. Groth, T. Hennig-Thurau, and G. Walsh, "Customer Reactions to Emotional Labor: the Roles of Employee Acting Strategies and Customer Detection Accuracy," *Acad. Manage. J.*, vol. 52, no. 5, pp. 958–974, Oct. 2009, doi: 10.5465/amj.2009.44634116.

[58] E. S.-T. Wang, "Displayed emotions to patronage intention: Consumer response to contact personnel performance," *Serv. Ind. J.*, vol. 29, no. 3, pp. 317–329, 2009, doi: 10.1080/02642060701846747.

[59] L. L. Price, E. J. Arnould, and S. L. Deibler, "Consumers' emotional responses to service encounters: the influence of the service provider," *Int. J. Serv. Ind. Manag.*, vol. 6, no. 3, pp. 34–63, Jan. 1995, doi: 10.1108/09564239510091330.

[60] G. Jungwirth, *Geschäftstreue im Einzelhandel : Determinanten, Erklärungsansätze, Meßkonzepte*. Wiesbaden : Dt. Univ.-Verl. [u.a.], 1997.

[61] M. Meyer and S. Robra-Bissantz, "Smile through the Mask Emotion Measurement for Stationary Retail.pdf," in *34th Bled eConference Digital Support from Crisis to Progressive Change*, Bled, 2021, pp. 195–208. doi: https://doi.org/10.18690/978-961-286-485-9.

Squaring The Circle: Leading Companies in a Contradictory World

Die Quadratur des Kreises: Führende Unternehmen in einer Welt der Widersprüche

Hans-Paul Bürkner, Arindam Bhattacharay

BCG Henderson Institute, Boston Consulting Group
Boston, USA, buerkner.hans-paul@bcg.com
BCG Henderson Institute, Boston Consulting Group
New Delhi, India, bhattacharya.arindam@bcg.com

Abstract — In normal situations, leaders struggle to make cool, calculated decisions in a measured, unbiased, unemotional way. But in today's world there is nothing normal or predictable. The question is, how can business leaders make the right decisions when they face unfamiliar and volatile situations and when the consequences of making wrong decisions could have negative impacts on their company's brand, revenue, and valuation. The article gives an answer to what is a deeply personal challenge for leaders today. Heart of the problem is the way the fast and radically changing "real" world clashes with our own mental model of a "familiar" world that has developed over many years. This clash can potentially cause "cognitive dissonance" and it can disrupt the way leaders make sound, long-term, strategic plans. The authors show how business leaders can reinvent themselves and their company continuously and better manage the tradeoffs when faced with two equally unfavorable alternatives. They need to accept the world as it really is and not as they would like it to be, adapt to the world as it changes, and activate their personal and corporate navigational tools for recentering and guiding their companies through the choppy waters of conflicting and contradictory demands.

Zusammenfassung — In normalen Situationen fällt es Führungskräften nicht schwer, kühle, kalkulierte Entscheidungen zu treffen. In der heutigen Welt gibt es jedoch nichts Normales oder Vorhersehbares. Die Frage ist, wie Führungskräfte die richtigen Entscheidungen treffen können, wenn sie ungewohnten und volatilen Situationen gegenüberstehen und wenn die Folgen falscher Entscheidungen negative Auswirkungen auf Marke, Umsatz und Bewertung ihres Unternehmens haben könnten. Der Artikel gibt eine Antwort auf diese aktuelle persönliche Herausforderung für Führungskräfte. Kern des Problems ist die Art und Weise, wie die sich schnell verändernde „reale" Welt mit unserem eigenen, über viele Jahre gewachsenen mentalen Modell einer „vertrauten" Welt kollidiert. Dies kann potenziell zu „kognitiver Dissonanz" führen und die Art und Weise stören, wie Führungskräfte solide, langfristige strategische Pläne erstellen. Es wird gezeigt, wie Führungskräfte sich und ihr Unternehmen ständig neu erfinden und notwendige Kompromisse besser schließen können, wenn sie sich zwei gleichermaßen ungünstigen Alternativen gegenübersehen. Sie müssen die Welt so akzeptieren, wie sie wirklich ist und nicht so, wie sie es gerne hätten. Sie müssen sich an die sich verändernde Welt anpassen und durch aktivieren ihrer persönlichen und unternehmerischen Navigationsinstrumente ihre Unternehmen neu zentrieren und durch die unruhigen Gewässer führen.

I. TODAY'S REAL-WORLD DILEMMAS

We are living in a polarizing world of dizzying complexity and puzzling contradictions. For every one of us, these are unsettling times. But for leaders, who must plot the path forward for hundreds and thousands of people, these are exceptionally challenging times.

Not so long ago, the world was on a steady course to become ever more interconnected, ever more interdependent, ever more integrated. Globalization was celebrated as a good thing, improving the lives of billions of people. The spread of liberal democracy, good governance, and international institutions - all operating under a kind of Pax Americana - provided a stable environment for fostering creativity, innovation, and entrepreneurship. The remark- able advances in digital technology offered the prospect of greater connectivity, greater productivity, and greater economic development.

Now, all of a sudden, these articles of faith, which have shaped our view of the world over the past 30 years, are being over- turned. The rug of certainty is being wrenched from beneath our feet. So, what is driving this unpredictability? What is giving rise to the seemingly unbridgeable choices – dilemmas - facing business leaders today? Here are five of the deep and widening fault lines fragmenting the old world order (clearly, this list is not complete and is growing with time). In no particular order, they relate to globalization, climate change, geopolitics, digital technology, and tribalism.

A. Globalization

It used to be assumed that the world is much better off with increasing globalization. But, for too many people, this is not

the case anymore. In some respects, the word "globalization" has become a euphemism for wage, tax, regulatory, and environmental standards arbitrage. Nowadays, when business leaders relocate their factories, find new suppliers, or outsource part of their operations in order to offer consumers better and less expensive products and services, they are often cast as mercenaries greedily pursuing profits and blithely disregarding the negative impact on local communities. So how can they come to a balanced, fair-minded decision on the best way forward?

B. Climate Change

It is widely acknowledged that the looming environmental disaster caused by climate change must be tackled before it is too late. Business leaders accept that it is not only the responsibility of governments to address this existential crisis - - it is their responsibility too. But how, for example, should they respond to calls to meet zero-carbon emission targets in a fair and trans- parent way that does not put their profits at risk and their company at a competitive disadvantage?

C. Geopolitics

The dismantling of the "unipolar" world order, the rise of economic nationalism (as more countries pursue protectionist policies that favor their own companies), and the mounting geopolitical competition be- tween the world's two biggest economies - the US and China - present business leaders with a dauntingly difficult decision to make. It is one that encompasses not only business and economic factors but also factors relating to wider stakeholder issues such as social values and liberal democracy. Already, there are fears that companies will be forced to choose sides - or else. But how should business leaders negotiate this strategic conundrum without suffering some kind of retaliation or retribution that hurts their shareholders and stakeholders? Should they, for example, undertake a hugely costly relocation of a plant from a low-cost country hit with import tariffs as a result of the US-China trade war or wait patiently for the world to return to some kind of normality?

D. Digital Technology

The rise of digital technologies - for instance, artificial intelligence, machine learning, robotics, big data and advanced analytics, and the Internet of Things - will change every product and service and impact every workplace and every job. The best companies will become bionic, merging the finest attributes of humans and machines. But the transition from an industrial world to the digital world will not be painless. How can business leaders maximize the palpable benefits of these technologies while not only addressing the legitimate concerns of governments and civil society relating to data ownership, transparency, and privacy but also minimizing the potentially negative impact on their own employees? As the HR director of a global industrial company told us, his company faces a strategic dilemma: Should it slow down the program of digitization - even though this is regarded as being critical for its future competitiveness - because the resulting job losses and what he called the "hollowing out of the middle" are negatively impacting employees' morale and the corporate culture?

E. Tribalism

It is an ancient feature of the human condition that we gravitate toward our own kind, our own "tribe." In premodern society, this evolved as a survival strategy, with individuals realizing they were safer when they were with others than when they were alone. But in modern society, this tribalism can manifest itself in a negative way - as a suspicion, even a fear, of people from different ethnic groups, different religions, different genders, different generations. At a time when the world has been getting smaller - thanks to the integrative forces of globalization and digital technology - this wariness of the "outsider" is a troubling throwback to a primeval era. So how can business leaders build global companies and foster diverse communities when they must contend with a growing tribalism among their employees, among their customers and suppliers, and among the people in the different countries where they do business?

It goes without saying that business leaders have long had to deal with difficult dilemmas. But today, their task is harder because they must also answer to the many different people who can legitimately claim to have a stake in the company. In the past, CEOs had to worry only about delivering profits for the company's principal stakeholder - the shareholder. As the economist Milton Friedman put it: "There is one and only one social responsibility of business - to use its resources and engage in activities designed to increase its profits."[1] Now, however, they must worry about many different stakeholders - not only shareholders but also employees, governments, activists of all kinds, and local and national communities. All too often, these stakeholders have very different expectations and very different world views.

Of course, it is the job of leaders to make tough choices, pick winners, and take responsibility for the consequences. That's what they are paid to do. But the evidence is that they are finding this harder to do. In a study of the longevity of more than 30,000 public firms over a 50-year time- frame, our colleagues at the BCG Henderson Institute and researchers from Prince- ton University found that "businesses are disappearing faster than ever before."[2]

To stop this corporate malaise, many CEOs embark on big, ambitious transformation programs to deal with a changing world. But, in doing so, they overlook one glaringly obvious fact: they, themselves, almost certainly need to transform too if they are to make the right decisions. The reason for this lies in the way we, as human beings, think - the way our brain functions, processes information, and understands the world. Complex though it is, our brain is simply not built to deal with the scale, speed, and sheer complexity of the contradictory world that has emerged over the past years.

II. Our Mental Models: How We Process Information and Why It Matters Now

The world has always been complex. But as a result of some remarkable advances in the field of neuroscience, it is now possible to see that the way our brain processes this complexity in order to make decisions can be suboptimal, counterproductive, or even plain wrong - especially at a time when the contradictory fault lines are deepening and widening.

The first thing to understand is that we have all developed a mental model of the world around us. This view of the world - formed by our own unique mix of education and training, life experience, and the societal norms of our national and local communities - provides the context for our decision making.

The second thing to understand is that when we come to make a decision, we are heavily constrained by the physical way our brain processes, or computes, information. Since it requires an enormous amount of energy to function, it looks for ways to be as efficient as possible. Specifically, it looks for shortcuts to minimize "heat generation," such as simplifying and, as we say, jumping to conclusions. Also, it tends to compute different types of information in distinct cerebral regions. Analytical issues are tackled by the "left brain" while creative, social, and artistic issues are tackled by the "right

brain." Simply put, if one side is better developed than the other, it tends to dominate, often with problematic consequences when processing complex and conflicting information that requires both sides - for example, when a business decision has to take account of societal and cultural factors.

The simplification can manifest itself in different ways. Typically, we try to force-fit what we're seeing into our mental model. To do this, we use our pattern-recognition capability, which draws on a collection of cognitive biases designed to help us see the world as we want to see it. One of these is confirmation bias, where we look for data that supports our preconceptions. This can happen, for example, when CEOs commission some work to test the feasibility of a new product idea and the researchers look for information that gives the CEOs what they want. Another is disconfirmation bias, where we ignore data that doesn't match our preconceptions.

When we fail to align the data from the real world with our mental model, there is a clash: a cognitive dissonance. Sometimes, we may rush to judgment, taking hurried, poorly considered decisions. Conversely, we may be paralyzed, freezing like a rabbit in the headlights, unable to make any kind of decision at all, good or bad.

In light of these insights, we spoke to dozens of senior business executives to understand how they process often conflicting data, how they resolve seemingly intractable dilemmas, and how they cope with the demands of a contradictory world. How do they manage to square the circle?

From these conversations, we have developed a practical two-pronged approach for doing just that. The first part focuses on the personal journey of transformation that leaders should undertake, and we have devised a series of individual interventions designed to help them do this. The second complementary part focuses on the corporate journey of transformation, and we propose a series of institutional interventions that leaders should introduce across their company.

III. SQUARING THE CIRCLE: A NEW AGENDA FOR BUSINESS LEADERS

As the world becomes more volatile, more unpredictable, and more unmanageable, it is essential that leaders do not go on the defensive, retreat behind closed doors, and underplay the problems. On the contrary, they should go on the offensive by building their own and their company's capabilities for recognizing and responding to the challenges, making tradeoffs, and finding solutions.

To do this, we recommend a three-step action agenda for leaders. First, they should accept the world as it really is with all its myriad contradictions - and not as they would like it to be. Second, they should readily adapt to the world as it changes. Third, they should activate their personal and corporate "navigation" tools for recentering themselves as individuals and their company in the face of all the conflicting demands on them.

A. Accept the World as it is – not as you would like it to be

We are programmed to see the world as we would like it to be. So when it isn't, when we are faced with complex, unknown (in our past experience), and contradictory information and issues, we let our cognitive biases take over, we simplify and stereotype, we let our analytical left brain quickly jump in and try to decode and explain. In some cases, we become overwhelmed by the situation, and this can lead to muddled thinking and poor decision making.

To prevent this from happening, it is important that leaders accept the world as it is. And by this, we mean that leaders must understand it, come to terms with it. As one neuroscientist told us, they should view the world as if they were "an observer in outer space." Counterintuitively, the failure to do so often afflicts the most successful leaders. This is because success can lead to complacency and overconfidence: "I have been successful in the past, so why shouldn't I continue being so?" As Claudia Sender Ramirez, former CEO of LATAM Airlines in Brazil, told us: "In my experience, many successful people who tend to oversimplify end up accepting a reality that they don't deeply understand." In other words, when the reality changes or the fault lines deepen, they struggle to deal with it.

Having said all this, it is important to note that by saying leaders should accept the world as it is, we are not saying that they should then do absolutely nothing about it. On the contrary, the point is: once leaders accept and truly understand the world as it really is, they will be in a much better position to find practical ways to disrupt and transform it.

A (a) Individual Intervention: Take Time to Reflect, Revise, and Expand Your Frame of Reference.

Leaders who have been raised in noisy, heterogeneous, fast-changing environments seem well suited to the world as it is today. Not for nothing are some of the world's biggest companies run by people born in developing countries such as India - which has 1.3 billion people who speak more than 20 official languages and practice all kinds of religion, from Hinduism and Islam to Christianity, Sikh- ism, and Buddhism. For example, Microsoft and Alphabet are run by Indian-born executives: Satya Nadella and Sudar Pichai, respectively.

Likewise, executives who have been posted to offices around the world, and see for themselves how others do things, have prospered. A senior European executive of a global consumer goods company with a policy of sending high-potential managers on tours of duty in foreign markets told us how the experience had taught him to reframe the world as he found it and never to take anything for granted. "Wherever I was sent," he explained, "I had to learn how to very quickly feel at 'home.'"

But it is not necessary to be born in or posted to such multidimensional environments to be a successful leader. It is necessary, however, to find ways to suppress our natural inclination to impose an artificial order shaped by our own mental models - our own preconceptions, particular biases, and personal preferences.

One way is to step back, take time to reflect, engage in physical activity, and in some meaningful way disengage from the daily hubbub. For example, Jack Dorsey, CEO of Twitter, has a variety of strategies to clear his cluttered mind and become, as he puts it, "performant." This includes meditating twice a day (once in the morning, once at night), walking five miles to work twice a week, and writing about his day or journaling every evening.[3]

Another way for leaders to stop their brain from becoming overwhelmed by the unfamiliar is to expand their frame of reference - in effect, broaden the portfolio of patterns their brain uses to recognize new stimuli. Neuroscientists now appreciate the extraordinary "plasticity" of the brain, and this knowledge can be turned to leaders' advantage: they can rewire their brain by traveling far and wide, encountering different worlds, different ways of life and culture, different ways of doing things. For example, if you operate in the private sector, find out how the public sector works. If you work in the US or Europe, visit businesses in Africa and Asia. If you run a big

business, make a point of meeting the founder entrepreneurs leading some new, small, innovative companies.

One CEO in India told us that, in today's fast-changing world of technology, she makes it a point of meeting at least one "interesting" startup every quarter. "I get to see the world as viewed through a different pair of eyes, and always learn something new," she said, "and it has taught me not to take my competitors for granted and always question the status quo."

But the traveling should not only be physical. It should also be intellectual. If you allocate an hour a day - five days a week - to reading, reflecting, and learning something new, you will see the benefits of what has been called "compound learning." Warren Buffett, the billionaire investor, spends 80% of his time reading and thinking because, as he puts it, knowledge "builds up, like compound interest."[4] Similarly, Bill Gates, Microsoft's cofounder, makes a point of stretching his mind by reading about 50 books every year - everything from literary fiction and thrillers to science, psychology, history, and memoir. "Every book teaches me something new or helps me see things differently," he once said. "Reading fuels a sense of curiosity about the world."[5]

The breadth of vision, or perspective, is something that headhunting firms are increasingly seeking in future leaders. Filiep Deforche, a senior leader at Russell Reynolds Associates, told us that they are on the lookout for potential leaders with "a large span," explaining that "aero planes need two wings to fly, and if they only have one - they crash."

A (b) Institutional Intervention: Develop Diverse Leadership Teams

Just as individual leaders can get a better understanding of the world as it really is by broadening their own portfolio of patterns, so institutions can do this by developing diverse leadership teams comprising individuals who each bring their own differing sets of pattern-recognition capabilities.

Until recently, it was not uncommon to see major companies led by teams of people from remarkably similar backgrounds. This was the case not only in the US and Europe but also in India, Japan, and China, among other places. Things are starting to change, albeit slowly. If companies are to see the world as it really is, they will need to accelerate the process of developing diverse leadership teams that properly reflect the full range of ethnic, gender, demographic, and neurological interests among their stakeholders. It is not enough, however, simply to recruit a diversity of people. It is also essential that these diverse people get exposed to a diversity of experiences on a regular basis. Like the CEOs, they too must embark on their own personal journey of transformation - traveling, taking up posts in countries far from home, and reading widely.

By developing a diverse team, companies can build the best defense against the clear and present danger of group-think and un- lock new solutions to troubling problems. The CEO of a leading European industrial company told us how the creation of a diverse team helped him respond to a sudden regulatory change in Russia. The top executive team at the company's headquarters had no clue how to tackle the problem caused by the new regulations. So, to find a solution, he put together an international team of leaders who had dealt with similar changes in their own countries and who looked at the "facts" in a very different way than the executives at the company's HQ.

B. Adapt to the world as it changes

If leaders accept the world as it really is, then they must also, by implication, adapt to the world as it turns - and that means being ready and willing to change constantly because the world doesn't stay the same.

Of course, such an injunction is nothing new. In the 1860s, Charles Darwin first talked about "the survival of the fittest." Over the years, his words have been misconstrued as meaning the survival of the fastest, the biggest, the tallest, the cleverest. Actually, he used the word "fit" not as a synonym of some athletic or other prowess but rather as a description of something that is best adapted to its specific environment. All living species have learned to survive by constantly "refitting" or adapting to the changing world around them. So, what practical steps can leaders and their companies take to do this too?

B (a) Individual Intervention: Be Open-Minded and Outward-Looking

One way leaders can become more adaptive is to be more proactively open-minded and outward-looking, more willing to listen to arguments that challenge their own way of thinking their own mental model. All too often, people talk, or even shout, across each other. Today, this can be seen in the way so much public discourse is conducted, with one group of leading thinkers including the cognitive psychologist Steven Pinker, the business writer Malcolm Glad- well, and the novelists Margaret Atwood and Salman Rushdie recently venting their frustration in Harper's Magazine, regretting the growing "intolerance of opposing views" and the "vogue for public shaming and ostracism."[6]

But what is happening in public is also happening in private, around the boardroom table. There is often no willingness to hear the other point of view, openly engage in meaningful debate, and accept the many contradictions that different parts of the same company face in different parts of the world.

If leaders are to counteract this suffocating narrow-mindedness, they must, as Baudouin Prot, former chairman and CEO of BNP Paribas, told us, let the "fresh oxygen of different views and ideas" flow through the boardroom. They should ask questions, not give answers. They should build upon ideas, not find ways to knock them down at an early stage.

For one thing is certain: without this openness, there can be no change or adaptation, and without change or adaptation, there can be no progress, no enduring success. As a newly installed CEO confided in us: "I know that I am not right and cannot be right all the time. But no one in my leadership team is willing to offer me a counterpoint or challenge my ideas - however much I encourage them to do so. I now realize that we have all grown up in a culture where the CEO is the unquestioned boss. To address this, I have come to the conclusion that I will need to bring someone very different from outside into my leadership team."

Another, and somewhat unconventional, building block for becoming more adaptive is to develop a richer vocabulary for understanding the world in all its kaleidoscopic variety. One way to do this is to study the liberal arts, which were first proposed by Aristotle as an essential part of a rounded education. Too often, they are haughtily dismissed as "soft" subjects, and it is striking how few top executives study the liberal arts. In the main, business leaders prioritize people with left-brain scientific and technological skills and MBA degree holders who learn problem solving through the case study approach. But by studying the liberal arts, leaders can strengthen their right-brain capabilities and thereby improve their ability to make sense of a complex, messy, irrational world - and make effective decisions.

One of the great advocates of the liberal arts was the late Steve Jobs, who was among the few business leaders of science and technology companies willing to speak up for the humanities. As he observed: "It is in Apple's DNA that technology alone is not enough it's technology married with

liberal arts, married with the humanities, that yields us the results that make our heart sing."[7]

B (b) Institutional Intervention: Promote Openness with Decentralized, Distributed Decision Making.

It is clear that individual leaders should be receptive to alternative views and alternative ways of doing things. As Ms. Ramirez said to us, "It is a good idea to try to reinvent yourself every 10 years or so." Equally, institutions should be similarly open - and this has never been more important than today. Indeed, such is the pace of change taking place in different ways in different parts of the world that it is no longer reasonable to think companies can adapt to every local stimulus by operating a top-down, command-and-control approach to decision making. Instead, companies should harness the energy of diverse teams stationed closer to the action. As Bob Black, former group president of Kimberly-Clark Corporation, phrased it, they should "turn the pyramid upside down."

Increasingly, some major companies are promoting an institutional openness by empowering local and frontline leaders, giving them the authority to make rapid, on-the-spot decisions so that they can respond to new challenges and capitalize on new innovations that so often emerge on the periphery rather than at the center. The CEO of one leading Latin American corporation told us how he is trying to "invert" the normal rules and put the business in the "driver's seat." As he explained, the company doesn't have an official corporate headquarters. Instead, it has a "thin layer" of leaders at the top, and their task is to serve "as an enabler," offering support for people operating in a series of what he called "centers of gravity."

C. Activate your personal and corporate navigational tools for recentering yourself and your company

In addition to accepting the world as it really is, and adapting as it changes, leaders and their companies must develop a common set of values and goals that will help them steer a steady course through these turbulent, conflicting, and contradictory times. Yes, individuals and institutions must make compromises - that's how they adapt - but they must nevertheless remain true to themselves. That is the basis of trust, and trust is a vital commodity in business. It is hard to win and all too easy to lose. Nobody wants to do business with people and organizations that blow one way and then the other with each new wind of change. And in the current environment, it is clear that the winds of change are blowing as hard as they ever have - and from every direction.

C (a). Individual Intervention: Switch On Your Personal Compass.

As individuals, leaders should switch on what we call their "personal compass." Many people talk of "purpose," but we think this word is best reserved to describe a corporate mission that goes beyond the narrow pursuit of profit. We use the word "compass" to describe the set of principles or codes that are core to individual leaders and guide them in their personal and professional life. As a leader, you must ask yourself three fundamental questions: Where am I going? Why am I going there? How am I going to get there?

Your compass is your personal tool - unique to you - that helps you answer the third question: how you navigate your way to your destination. Of course, you may need to alter the route you take as you encounter new challenges, new obstacles, new problems. This is all part of adapting to the world as it really is. But what you don't change is how you travel: for in-stance, how you treat the people around you, how you negotiate with customers and suppliers, how you address their strengths and weaknesses, and how you openly acknowledge your own strengths and weaknesses too.

As Cipla's Mr. Vohra explained to us: "One of the main reasons why I decided to join the company was the answer I received to my question to the promoters (and principal shareholders): 'Who, in your opinion, are Cipla's principal "shareholders" and what do they expect from the CEO?' Their answer that 'we were set up to serve patients and save lives' was aligned with my deeply held views, and has been my 'line in the ground,' my personal compass which guides my decisions whenever I am faced with conflicting pressures."

C (b). Institutional Intervention: Center Everyone Around an Energizing Common Purpose.

In a world of contradictions, diametrically opposed forces, stakeholders pulling in different directions, and diverging expectations between Gen-Zers, Millennials, and Baby Boomers, companies need a way to center everyone around an energizing common purpose. A few years ago, companies tended to talk about their "mission statement": a pithy sentence or two that expressed their raison d'être. This has since evolved into what is now called the firm's "purpose" - a powerful "magnet" that pulls individuals and teams together around common goals and gives them the motivational energy to achieve them.

Many leadership teams start to define their purpose by asking themselves the existential question: Why do we, as a company, exist? There are clear advantages to doing so. According to research by BrightHouse, a BCG company, "brands with a high sense of purpose have experienced a brand valuation increase of 175% over the past 12 years, compared to the median growth rate of 86%."[8]

In our view, it is important to see purpose as the institution's corollary of the personal compass. The two are connected. They are two sides of the same coin. If there is a mismatch between the leader's personal compass and the company's purpose, then there may be a problem. Equally, leaders, guided by their own personal compass, can offer inspiration to the rest of the organization. "The leader has to define what the company stands for," said Roland Busch, incoming CEO of Siemens, during an interview for a newly published BCG book titled Beyond Great: Nine Strategies for Thriving in an Era of Social Tension, Economic Nationalism, and Technological Revolution (Public Affairs, 2020). They have "to give something meaningful to the company."

Echoing these sentiments, Microsoft's Satya Nadella said: "The most useful thing I have done is to anchor us on the sense of purpose and mission and identity. There is a reason we exist."[9] He could well have added "in today's complex world of heightened contradictions and increased polarization."

IV. THIS TIME ITS PERSONAL: WHY LEADERS MUST TRANSFORM THEMSELVES, NOT JUST THEIR COMPANY

It has become an axiom of business that change is the only constant. In today's world, the word "transformation" might be better than "change." As Mr. Prot put it to us: "We can only underestimate the challenges we face these days." But too often, business leaders launch bold corporate transformation programs by issuing directives from the executive suite, demanding that employees alter their working habits and forgetting that real, enduring change starts at the top - with the leaders. This is why it is time for business leaders to take a long, hard look in the mirror. If their corporate transformation

is to succeed, they need to transform as much as, if not more than, their employees.

And when we say "business leaders," we mean board members as well as C-suite executives because they are often the laggards, holding onto an outmoded way of doing things. "It is very difficult for CEOs to reinvent themselves continuously," one senior nonexecutive told us. "It is better for boards to find the right CEO for the right context." In other words, if you're in a growth phase, hire a CEO with an entrepreneurial mindset, and if you're in crisis, choose a CEO with conservative costcutting credentials.

But, in our view, this is an outdated perspective. Such is the pace of change that companies simply cannot afford to chop and change executives with each new economic phase. It is just not practical. Not only that, but very often, global companies may be expanding in one particular business or part of the world while at the same time shrinking in another. In other words, they need CEOs who can deliver bottom-line savings and generate top-line growth at the same time. Indeed, there is evidence that the best-performing CEOs are doing precisely this. Recent research by the BCG Henderson Institute found that while most companies perform poorly during a down- turn, some 14% manage to defy the odds by increasing sales growth and expanding profit margins.[10]

So what's the secret? How can business leaders reinvent themselves and their company continuously? How can they better manage the tradeoffs when faced with two equally unfavorable alternatives? How can CEOs lead effectively in a world of contradictions? They need to do three things: accept the world as it really is and not as they would like it to be, adapt to the world as it changes, and activate their personal and corporate navigational tools for recentering and guiding themselves and their company through the choppy waters of conflicting and contradictory demands.

Accept, adapt, activate. It sounds beguilingly easy. But be in no doubt: it is hard to do. It means understanding and then reconfiguring, reframing, and expanding how you think. It means coming to terms with your weaknesses and fallibilities. Bluntly put, this can be uncomfortable, disconcerting, humbling. Do it right, however, and it can be rewarding for you and your company.

REFERENCES

[1] First articulated in his book Capitalism and Freedom (1962) and reprised in the New York Times, A Friedman Doctrine - The Social Responsibility of Business Is to Increase Its Profits, 1970.

[2] BCG, The Biology of Corporate Survival, 2016.

[3] CNBC, Billionaire Jack Dorsey's 11 'Wellness' Habits: From No Food All Weekend to Ice Baths, 2019.

[4] CNBC, How Warren Buffett Learns, 2018.

[5] Time, Bill Gates Discusses His Lifelong Love for Books and Reading, 2017; GatesNotes: The Blog of Bill Gates.

[6] Harpers, A Letter on Justice and Open Debate, 2020.

[7] New Yorker, Steve Jobs: Technology Alone Is Not Enough, 2011.

[8] BCG, BrightHouse.

[9] BCG, Beyond Great: Nine Strategies for Thriving in an Era of Social Tension, Economic Nationalism, and Technological Revolution, Public Affairs, 2020.

[10] BCG, Advantage in Adversity: Winning the Next Downturn, 2019.

International expansion of „Compliance"

Internationale Expansion von "Compliance"

Malte Pehl, LL.M.

Rechtsanwalt, Fachanwalt für Arbeitsrecht, Fachanwalt für Handels- und Gesellschaftsrecht, Compliance Officer

Abstract – The aim of this paper is to give a compact introduction to the term Compliance and its development, including its latest international expansion.

Zusammenfasung – Das Ziel des vorliegenden Beitrags besteht darin, eine kompakte Einführung in den Begriff Compliance zu geben und dabei auch seine Entwicklung und die aktuelle internationale Expansion aufzuzeigen.

I. COMPLIANCE AS A TERM

The term "compliance" originally comes from American law and means observance, agreement with the law, or consent [1]. In general, the term is understood as agreement with the rules. According to the general worldwide understanding, the now "fashionable" term encompasses the entirety of all measures to ensure compliance with legal requirements and non-violation of legal prohibitions by companies, board members and employees [2]. The term compliance is often used as an "abbreviation" synonymous with the terms "corporate compliance", "compliance management" or "compliance management system" [3].

A. Compliance rules for enterprises

General compliance rules and prohibitions can arise not only from externally set legal requirements, but also from internal rules of conduct ("guidelines" or "policies") or contractual agreements [4]. What is meant by this is that the companies as a whole behave in accordance with the law. It is not the corporate policy and strategy of the company management in the sense of right or wrong entrepreneurial decisions that is in the focus of compliance, but rather, about ensuring that management acts in accordance with the law [5].

B. Corporate Compliance

The term "corporate compliance" has also grown and spread. In addition to measures to ensure lawful behavior in the company, this also embodies measures for early risk detection and risk minimization [6]. These measures also recognize that, from a company perspective, compliance obligations are part of the organizational responsibilities of management.

C. Compliance Management Systems (CMS)

The term Compliance Management System ("CMS"), which is also appearing more and more frequently, is understood in abstract terms as an entrepreneurial organizational system that is intended to ensure and further develop compliance in the company. As an example, CMS is referred to as "the entirety of the measures and processes set up in a company to ensure compliance with the rules" [7].

The German legal literature likes to fall back on the so-called IDW PS 980 standard when explaining the CMS term [8]. Under the abbreviation "IDW PS 980", the Chamber of Public Accountants has drawn up a standard including sample formulations for test reports through the Institute of Auditors in Germany e.V. ("IDW"), which is used to properly review compliance systems. According to this, a compliance management system is to be understood as "the principles and measures introduced by a company on the basis of the objectives set by the legal representatives, which aim to ensure that the legal representatives and employees of the company and, if necessary, third parties behave in accordance with the rules, ie on compliance with certain rules and thus on the prevention of significant violations (rule violations) "[9].

From a legal point of view, a compliance organization in the sense of a CMS is only required if it is necessary and reasonable [10].

The type and scope of the measures depend on the size, industry and circumstances of the company [11]. The creation of a compliance area of responsibility or a separate department through assignment to one of several managing directors, appropriate selection, instruction and monitoring of employees, ensuring clear competencies and areas of responsibility in the company, sufficient information supply and the prosecution of suspicious cases come into consideration.

II. INTERNATIONAL DEVELOPEMENT

Generally known as the "motherland of compliance", the first authorities and courts in the USA actually began to take compliance regulations into account in the prosecution and sanctioning of companies [12].

For the first time during the Cold War, a set of legal requirements was created under the umbrella term compliance, in order to enable the US industry to keep up with the rapidly changing and severely sanctioning US export control legislation and its delivery restrictions into the "Eastern Bloc states" [13]. Since then, the USA has steadily developed into the "motherland of compliance" [14]. The extensive investigative proceedings of the US Department of Justice and the US Securities and Exchange Commission (SEC) and their considerable sanctions against companies under the Foreign Corrupt Practices Act of 1977 (FCPA) against numerous companies in and outside the USA also play a decisive role [15].

A. Origin in the USA

The US export control and anti-corruption compliance rules and guidelines were and are also to be observed for non-Americans and thus also for European companies in their activities in the USA, as they also apply to companies that are not listed on a US stock exchange or are not "closely related"

to the stock exchange [16]. In this respect, the general compliance requirements from the Sarbanes-Oxley Act ("SOX") passed in 2002 after the Enron and Worldcom scandal must also be observed.

According to this, "the USA can claim jurisdiction in criminal matters even over companies that are not established in the USA or are listed on the stock exchange if an act has taken place on the territory of the USA. In the investigative practice of the authorities, a money transfer via an account in the USA or even e-mail with recipients who are in the USA is sufficient."

To avoid a misunderstanding: the application of the "Foreign Corrupt Practices Act" introduced in 1977, which criminalizes the bribery of foreign public officials and the associated incorrect accounting practices, is also relevant for every type of company [17].

The "US Sentencing Guidelines" (Federal Sentencing Guidelines), which came into force in 1991 and were substantially revised in 2004, are of particular importance for the requirements of a compliance system from the US point of view. In the USA, this means that companies can be held criminally responsible if an employee with power of attorney commits a criminal offense in the context of his employment relationship with the intention of benefiting the company. The amount of the penalties imposed on individuals and companies in the event of a conviction under federal law is based on the sentencing provisions of the aforementioned US Sentencing Guidelines, even if, according to judgments of the US Supreme Court, these are no longer mandatory for constitutional reasons. In the case of sanctions against companies, the amount depends crucially on whether the company has tried to prevent criminal offenses through an "effective" compliance system or not [18].

B. Development outside of the USA

Compliance has gained even more global importance since the Convention to Combat Corruption of the Organization for Development and Cooperation (OECD) of December 17, 1997, which came into force in February 1999. At present, 41 states have ratified the convention. Building on this, the UK Bribery Act and, in 2010, the OECD Good Practice Guidance on Internal Control, Ethics and Compliance guidelines have also been introduced [19].

In addition to these regulations, which are based on the fight against corruption, there are other international institutions that have published proposals on compliance and are thus actively involved in the further development of international standards. This can be seen especially in the case of the OECD. Here it important to mention The International Chamber of Commerce (ICC). With the participation of the business community, it has drawn up various practical guides on essential aspects of compliance, such as the selection and due diligence of business partners or, most recently, a comprehensive "ICC Ethics and Compliance Handbook".

The latest aspect of the tightening of compliance within the European Union is likely to be the EU Whistleblower Directive 2019/1937, which came into force on December 16, 2019 and must be implemented in national law by the member states by December 31, 2021. Not only employees who report grievances are protected, but also applicants, former employees, supporters of the whistleblower or journalists. These persons must be protected from dismissal, demotion and other forms of discrimination.

The protection only relates to the reporting of abuses related to EU law, such as tax fraud, money laundering or offenses related to public contracts, product and traffic safety, environmental protection, public health and consumer and data protection (the EU encourages national Legislators, however, to expand this scope in national law).

Another potential need for advanced compliance regulations may arise with the ongoing international digitalization. There surely are requests to government authorities to control the implementation of high-tech solutions to monitor their effects on the labor market [20].

C. National development in Germany

The "starting point" of the development of compliance in Germany is often seen in Section 93 (1) sentence 1 AktG and Section 91 (2) AktG [21]. However, the judgment of the Federal Court of Justice on ARAG / Gamenbeck from 1997 often serves as a basis for assessing breaches of corporate duty by executive and supervisory boards [22].

There, the BGH ruled on the duty of the supervisory board to assert claims for damages against members of the executive board and, among other things, made it clear that the supervisory board, due to its task of monitoring and controlling the activities of the executive board, is obliged to check the existence of claims for damages by the AG against executive board members. In the context of the examination of the conduct of the board of directors, it is (however) to be given a broad scope of assessment. It was also decided that the Supervisory Board, should it come to the conclusion that the Management Board has made itself liable for damages, must assess, on the basis of a careful and properly carried out risk analysis, whether and to what extent the judicial assertion will result in compensation for the damage incurred by the AG. If the supervisory board comes to the conclusion that enforceable claims for damages exist, the supervisory board has to pursue these claims in principle according to the above-mentioned decision of the BGH.

In the area of criminal law, the company's management is also primarily concerned with aiding and abetting offenses, but an offense (by actively doing or not doing) is easily conceivable, as has recently been the case with various criminal proceedings against well-known German managers for breach of trust, Section 266 StGB, . In addition, pursuant to Sections 9, 30, 130 of the OWiG a company can be held liable and be fined in case, a member of the body authorized to represent the company, culpably neglects supervisory measures that are necessary to prevent legal violations by employees in connection with its business activities.

However, since criminal proceedings in Germany can only be carried out against individuals so far and therefore only an administrative offense procedure with correspondingly more limited sanction options can be considered in relation to illegal actions against companies, the German legislator is working on a so-called Association Sanctions Act (VerSangG). This was foreseen in the coalition agreement of the federal government from 2018 and should initially be passed in 2021 before the next federal election and then also enable tougher sanctions directly against companies. It is now clear that a corresponding law will no longer be passed before the federal election [23].

In the corresponding draft, it is explicitly provided that with an "appropriate" compliance management system, the sanctions will be completely eliminated or at least lower. An anonymous whistleblower system and internal investigations are particularly emphasized in this context and will be able to trigger concrete legal consequences.

The German "Supply Chain Act" ensures further compliance regulations that go beyond their effects within Germany. According to the new law, which was passed by the German Bundestag on June 11, 2021, companies should take responsibility if human rights or environmental protection regulations are not complied with in the supply chain - for example if children are involved in the production of preliminary products or if illegal chemicals are used or not properly disposed of. Associated with this are new or increased duties of care and documentation as soon as the majority of the new regulations of the law comes into force on January 1, 2023.

III. CONCLUSION

The compliance management system should initially ensure that no legal violations are committed; The requirements for the personal punishment and liability norms for the management are not met. If this is also not successful, the compliance management system can be used to argue for the lowest possible fine or punishment [24].

The compliance management system therefore enables a defense with three lines of protection: (1.) Avoidance of legal violations (2.) Avoidance of personal punishments and liability (3.) Ensuring the lowest possible punishment or personal liability.

It should also be mentioned at this point that a CMS can have positive effects on securing and promoting the reputation of the company towards all stakeholders (business partners, banks, investors) [25] or can also be helpful for recruiting [26].

Regarding the further development of individual compliance rules it is obvious that "the sky is the limit", which means in theory there are no limits for additional rules and regulations and we see a clear tendency that governments (here including the European commission) rather add new regulations than take back existing ones.

REFERENCES

[1] Küttner, Wolfdieter, Personalbuch, 1. Begriff. Rn. 1-2a, beck-online.

[2] Baumbach/Hueck/Zöllner/Noack GmbHG § 35 Rn. 66, beck-online.

[3] https://www.haufe.de/compliance/management-praxis/compliance-management-systeme/compliance-management-system_230130_455824.html;https://www2.deloitte.com/de/de/pages/risk/articles/compliance-management-system.html; https://www.infineon.com/cms/de/about-infineon/investor/corporate-governance/compliance/compliance-management-system/; https://www.daimler.com/konzern/compliance/compliance-management-system.html, all last access on 12.09.2021.

[4] Grützner/Jakob (2015), Compliance von A-Z, Compliance; IDW PS 980, 2. Rn. 5, page 3.

[5] BGH 21.4.97 – II ZR 175/95, NJW 97, 1926 – ARAG/Garmenbeck.

[6] Baumbach/Hueck/Zöllner/Noack GmbHG § 35 Rn. 67, beck-online.

[7] Park, Tido, (2019) Kapitalmarktstrafrecht, Teil 2: Kapitel 2: Kap. 2.1. Criminal-Compliance Rn. 40.

[8] Hauschka/Moosmayer/Lösler, Corporate Compliance, 2. Abschnitt. Grundelemente eines Compliance-Systems 7. Kapitel. Compliance-Überwachung/-Verbesserung § 43. EDV-Lösungen in der Praxis Rn. 68; Park, Kapitalmarktstrafrecht, Teil 2: Kapitel 2: Kap. 2.1. Criminal-Compliance Rn. 40.

[9] IDW PS 980, 2. Rn. 6, page 3.

[10] Baumbach/Hueck/Zöllner/Noack GmbHG § 35 Rn. 67, beck-online.

[11] IDW PS 980, 4. Rn. 23, page 5.

[12] Moosmayer, Klaus, Compliance, B. Rechtsgrundlagen der Compliance und Haftungsrisiken Rn. 17-30.

[13] Maloney, J.K., Gaming Law Review, Vol. 8, No. 2, 2004.

[14] Hauschka/Moosmayer/Lösler, Corporate Compliance, 1. Abschnitt. Einführung und rechtliche Rahmenbedingungen 1. Kapitel. Einführung § 1. Einführung Rn. 73, beck-online.

[15] Wessing, Jürgen in: Wessing/Dann, § 1.

[16] Moosmayer, Klaus, Compliance, B. Rechtsgrundlagen der Compliance und Haftungsrisiken Rn. 17-30.

[17] Lenze, Sebastian (2014), Compliance, Internal Investigations und Beschuldigtenrechte, 2. Kapitel, Seite 44, Rn. 136.

[18] Moosmayer, Klaus, Compliance, B. Rechtsgrundlagen der Compliance und Haftungsrisiken Rn. 17-30.

[19] Hauschka/Moosmayer/Lösler, Corporate Compliance, 1. Abschnitt. Einführung und rechtliche Rahmenbedingungen 1. Kapitel. Einführung § 1. Einführung Rn. 82, beck-online.

[20] Gankova-Ivanova, Digitalization and labor market-perspectives and challenges, FDIBA Conference Proceedings, vol. 3, 2019, page 41-44 (44).

[21] Moosmayer, Klaus, Compliance, B. Rechtsgrundlagen der Compliance und Haftungsrisiken Rn. 10, beck-online.

[22] BGH, Urteil vom 21.04.1997 – II ZR 175/95; NJW 1997, 1926.

[23] https://www.compliancedigital.de/ce/verbandssanktionengesetz-in-dieser-legislatur-gescheitert-notwendigkeit-einer-regulierung-bleibt/detail.html, last access on 12.09.2021.

[24] Winkler, Janine, Die steuerliche Abzugsfähigkeit von Aufwendungen für Compliance-Maßnahmen und Geldsanktionen nach dem Verbandssanktionsgesetz, Der Betrieb 2020, page 1363.

[25] Sonnenberg, Compliance-Systeme in Unternehmen, Einrichtung, Ausgestaltung und praktische Herausforderungen, JuS 2017, page 917

[26] Weaver/Trevino, The role of human resources in ethics/compliance management – A fairness perspective in Human Resources Management Review 11 (2001), page 113.

This page is intentionally left blank

Compliance Rules: Renaissance of "Neo-Protectionism"?

Compliance Regelungen: Renaissance von "Neo-Protektionismus"?

Malte Pehl, LL.M.

Rechtsanwalt, Fachanwalt für Arbeitsrecht, Fachanwalt für Handels- und Gesellschaftsrecht, Compliance Officer

Abstract – The aim of this paper is to describe the connection between compliance rules and modern neo-protekionism and its potential for a strategic trade policy.

Zusammenfasung – Das Ziel des vorliegenden Beitrags besteht darin, den Zusammenhang zwischen Compliance-Regelungen und modernem Protektionismus sowie das damit verbundene Potenzial zur Nutzung für eine strategische Handelspolitik aufzuzeigen.

I. INTRODUCTION

This paper engages in the connection between compliance and the currently increasing worldwide neo-protectionism (which can be described as protectionism 4.0) and to what extent compliance rules can be used as a means for non-tariff trade barriers, i.e. as a strategic trade policy. The essay contains both economic and legal aspects. Its goal is not only to point out the current status quo of compliance and current state-of-the-art protectionism in order to raise awareness of the context at all, but ultimately promotes the need to study the impact of both to help affected companies to react appropriately and reasonable to current developments. With regard to Government trade policy, the essay seeks to promote a critical examination of compliance and protectionism and also to create an awareness that a protectionist effect surely can be achieved with a steady increase of national regulation of entrepreneurial activities (e.g, tightening of employment conditions or environmental protection), but on the other hand, however, this (over)-regulation can also affect the domestic economy more than the foreign economy and might backfire.

So where to begin?

II. FROM COMPLIANCE TO PROTECTIONISM

Those who want to get a lucrative business deal outside of northern Europe, North America and Japan quickly learn that smaller or higher hand money or other incentives are often the necessary pre-conditions for a deal to be made. Those, who pound on the relatively new keyword compliance and the corresponding "checklist", will find himself without a chance right from the beginning!

This applies to business as well as sports, politics and many other areas. If the provincial and formal legislature demands "appropriate" rules and a businessman even adheres to these and his potential own additionally set compliance policies, because he believes the role model USA and other emulating "global players" would do the same, this may be nice to look at from the provincial German frog's perspective, but the "Sommermärchen" (summer fairy tales) actually take place elsewhere [1]. The payment of cash in the context of the conclusion of a deal is of course representative for a grant of various benefits in connection with all kinds of different business transactions. So that, for example, the gifted house on Naxos for the Greece "supportive" works council chairman is just as relevant as the "just friendly" procurement of a rare place in the internationally private school (alternatively: University) for the "key account salesman" and its "of course, independently granted " discounts. But please do not get the wrong impression. Ethical questionable and/or illegal business can also be reported for the former "Exportweltmeister" [2] (world champion of export) and "Vorzeigerechtsstaat" [3] (role model for all free governments under the law) Germany [4].

The focus of this essay, however, lies on those constellations in which the entrepreneur or the enterprise violates internal or external requirements (in particular legal regulations) (for example environmental or health protection regulations) in order to obtain an economic advantage for himself - It looks at both one-sided and joint practices of several companies that are already violating compliance regulations or could violate them in the future.

Compliance often proves to be a naïve attitude by those who believe such rules are needed to make business relationships open, honest, and fair. The fact that they are often merely given as empty promises and are actually deliberately undermined or only practiced one-siddly in order to achieve strategic business advantages is often the historically established rule, especially in international business. This is particularly true in the age of the "re-industrialization" of the old industrialized countries. This was especially relevant in the past few years when it was asked again and again what compliance is good for, if it is not even to be considered [5]? Above all, (over-) motivated journalists, still give the impression that compliance is not only of paramount importance for global corporations, but also for the local middle class, since without an effective compliance management system employees, executives and companies themselves "risk it all". It is also said that compliance has been one of the dominant topics in corporate practice and legal literature for several years [6].

On the other hand, compliance in the USA is actually held in check by means of extensive internal investigations, which can also be carried out across borders by international companies [7]. In the end, penalties in the tens of millions or even billions have been handed out [8]. As early as December 2006, Christian Sapsizian was charged because of preparing certain crimes and violations of the US FCPA [9]. Mr.

Sapsizian was once a senior manager of Alcatel S.A., a well-known French telecommunications company whose shares were also traded in American stock exchanges. The prosecution accused him of having made illegal payments to officials of the Telecommunications Agency of Costa Rica. The us-prosecution accused Mr. Sapsizian even though he was acting exclusively outside the United States. Alcatel itself was not prosecuted. In June 2007, Mr Sapsizian made a confession to two courts for preparing for crimes and violations of the FCPA. He was sentenced on 23.09.2008 to 30 months imprisonment and three years' probation. He was also punished with a 261,500.00 US Dollar fine [10]. Even then, this case showed how far US authorities are interpreting the scope of the FCPA and pursuing corruption scandals in a Euro-Latin American affair that has little to do with the US. In Germany, however, this process was paid little attention.

The case shows very clearly that in addition to civil law consequences, criminal proceedings are possible and can have far-reaching (personal) consequences. In recent development, both the company itself and those responsible for the organization are personally affected. The VW "exhaust scandal", also referred to as "diesel affair" confirms this perception in the broad (German) public. Even Huawei does not seem to have accidentally got into the crosshairs of American investigators and trade politicians [11]. All just coincidence? All just isolated cases that only have in common that legal violations (supposedly) were committed?

Nor is it undeniable that states that are known for their institutionalized corruption and bribery are much less attractive to trading partners and investors and that, to a certain extent, have a noticeable negative effect on economic growth [12]. Brazil, for example, saw economic growth of 3% in 2013 and drop dramatically to -3.5% in 2015, mainly due to nationwide corruption scandals and associated political unrest, in the context of the elections of the new president (Brazil's "Mini-Trump") but then, according to current forecasts, should rise again to 2.5%.

Independently of this international aspect, compliance violations can even be criminally relevant to corporate governance at the national level, as the Federal Court of Justice has confirmed [13]. It cannot be denied that compliance regulations can also have a protective function for the company itself and its corporate leaders [14]. The case of "Bilfinger" and the former Prime Minister of Hesse, Roland Koch, may serve as an example here [15].

Some other examples can be seen in relatively recent German history. These examples include, the ADAC affair, that was triggered by fake participants and fake surveys, the "rail cartel" which resulted in penalty and compensation payments to the amount of almost 300,000,000.00 euros for Thyssen Krupp, Mercedes Benz and „the fake test driver" (around 20,000,000.00 euros damage), or even the HypoVereinsbank, which, due to their involvement in more than borderline Cum-Ex tax forms, a total loss of around 250,000,000.00 euros [16].

With regard to antitrust violations, both the Federal Cartel Office and the EU Commission imposed cartel fines totaling EUR 2.1 billion (Bundeskartellamt) and EUR 8.9 billion (EU Commission) on several hundred companies in the period from 2010 to 2014 alone [17].

Correspondingly impressive figures (with some German and, above all, a strikingly large number of Japanese events) also result for non-European antitrust authorities such as the US Department of Justice [18]. The corresponding antitrust proceedings concerned a large number of heterogeneous products from coffee to cables and crabs to automotive parts [19]. In many cases, they also had an international relevance (e.g. in the field of automotive parts). It must therefore be assumed not only that numerous customers were affected by them, but also that the corresponding competitors were often harmed to a considerable extent.

European data protection in accordance with the General Data Protection Regulation (GDPR) and the corresponding German implementation in the form of the Federal Data Protection Act (BDSG) are also bringing new fine proceedings and sometimes spectacular fines into the focus of companies and the general public. The German highlight is the fine of over 35 million euros imposed on the textile group H & M in October 2020 for the digital storage and use of very personal information about its own employees [20].

III. PROTECTIONISM AS A MEANS OF CHOICE

Since the election campaign of the former President of the United States, Donald Trump, and the present international sanctions imposed or still under discussion against North Korea, Iran, Saudi Arabia, Russia etc. the concept of protectionism has also returned to the focus of the general public [21]. The political dispute between free trade and protectionism did not just begin with the election of Trump in the 21st century. Trade disputations have been taking place between the USA and China for some time now [22]. An example of these difficulties can be seen in the difficult market for solar cells [23].

However, the EU and its member states, have become the target of the later US protectionism and demand or impose various new punitive tariffs for steel imports and aluminum imports [24].

It should not be forgotten that vocabulary such as "trade war", not only accompany the current world events, but were also seen in also the past, again and again and will most likely be seen in the not so distant future [25]. Currently, there is the widespread impression that German (business) politicians, in particular, are mourning the term of the former President of the United States, Barack Obama. These business politicians are obviously forgetting that he too had developed protectionist tendencies or forced himself to do so because of internal pressure to protect US companies [26].

Protectionist measures are increasingly the subject of (international) court decisions, which show that the various states are indeed constantly trying to operate on the border with international law or (clearly) beyond protectionism in favor of the domestic economy. As an example, Hungarian tax law mentions that employers (in fact: exclusively Hungarian banks) have the possibility to grant their employees credit for services and benefits in kind on favorable tax terms [27].

Regardless of this, however, it should be emphasized at this point that protectionism cannot per se be "demonized" as harmful and false. Because protectionism also has causes and reasons [28]. Too often in Germany, it is pointed out very sweepingly that protectionism (most recently, of course, that of the "impossible" Mr. Donald Trump) harms the entire global economy [29]. However, it quickly becomes clear that there is no one global economy that would have to bear the negative consequences of protectionism. So the "bitter" truth is, first of all, that protectionism not only produces losers, but also includes "individual profit potential." A blanket evaluation can

therefore only be discouraged and so this essay should also contribute to the necessary differentiating consideration and evaluation.

IV. FROM NEOPROTECTIONISM TO PROTECTIONISM 4.0

Neo-protectionism is therefore included under strategic trade policies. It is a dazzling, multi-layered term for that part of protectionist measures that does not use the classic instruments of protectionism. These measures include tariff barriers such as customs duties, subsidies or the acquisition of research and development costs and non-tariff barriers such as import or export quotas and embargoes [30].

In general, tariffs or subsidies seek to make non-competitive domestic producers competitive by setting extra charges on the prices of foreign suppliers or by subsidizing the costs of domestic suppliers. Quotas aim to protect non-competitive domestic producers through limited import volumes and the resulting price increases. Since the preservation of non-competitive providers permanently reduces world welfare, since the end of the Second World War attempts have been made to overcome protectionism in the interests of more free trade.

For that reason, even the General Agreement on Tariffs and Trade (GATT) of 1947 outlawed protectionism. In the long term they never really overcame it, since the total removal of protection would compel world trade partners to make their competitive sectors more efficient of possibly shut them down. This could result in a painful structural change. This outcome is something the political elite would rather avoid. This area of tension could not be fully resolved by the WTO since 1995 and most recently in 2013 with the most recent version of the free trade agreement [31]. The current discussion about the North-Atlantic Free Trade Agreement (TTIP) between the EU and the US provides another current example of these conflicting interests [32].

Nevertheless, there were longer periods of considerable liberalization, but most of them were confined to the interior of free trade areas or common markets such as the European Union. Their public images, however, were often associated with more protectionism, which, however, used new terms and reasons.

For many years, the "voluntary export restriction" has been successfully applied by emerging economies and tolerated by GATT, as they are supposed to protect the importing country's beleaguered import substitution sector from competitive pressure on the voluntary decision of the exporting country. Often, these were trade measures to obtain legal anti-dumping duties and to participate in the price increase in the importing country triggered by the reduction in supply.

The argument to create more price-cutting competition by building new suppliers in tight markets, such as the market for passenger aircraft (Airbus) was also used to justify protectionist subsidies and was often rationalized under the label "Infant Industry Protection", which was originally intended to protect the development of a hitherto non-existent industry in developing countries as a temporary exception protectionism. In fact, it is a political instrument to flexibly protect and develop the national position in world markets, and thus an instrument of "strategic trade policy" to promote national interests.

The range of arguments for justifying such "neo-protectionisms" vary from the alleged protection of the importing country, such as the "voluntary export restriction", to the prevention of price advantages due to social dumping abroad, to the contingent treatment of foreign imported products with ecological or moral-political arguments. Social dumping refers to competitive advantages of foreign countries, e.g. lack of social welfare, child labor, etc. Ecological arguments usually refer to allegedly low environmental standards or the use of toxic substances in imported goods or the reference to product characteristics that may not have been met. A good example of this is the limitations set on exceeding CO_2 emissions from diesel vehicles, whereby the limit values that are set are hardly, or not at all, attainable in the current state of the art. Ecologically decreed extreme regulations thus become the breaking point of fair trade relations, which can thus easily be exploited in a protectionist manner. As a neo-protectionism you can also look at the US campaign against Volkswagen. In this instance the VW management itself was responsible for their own demise. Their handling of their US branch was so poor that it made it virtually impossible for Trump to not take a swing at them. It is also to be kept in mind that the "Dieselgate scandal" arose already during the second term of President Barack Obama. Obama was rather "quiet" and careful in all aspects, whereas, his successor, Donald Trump showed a much more aggressive and open approach to protectionism [33].

Furthermore, references to undemocratic or totalitarian political systems in exporting countries or unacceptable policies are used to justify restrictions on international trade and capital movements. For example, in some countries direct and open embargoes are used; in other completely similar cases, however, local events are generously overlooked and certainly not "sanctioned".

Frequently, this is also limited to discriminatory statements, review measures or delivery harassment, where the protectionist effect is achieved only through the media.

The current dealings of the Western world with Iran, Russia and, on the other hand, Turkey quickly show the complexity of global economic interdependence and its consequences.

And Germany? Meanwhile, German economic leaders also want to "protect" German companies and are obviously working on new programs to strengthen and further develop German industries [34]. Above all, investments and business purchases from China are increasingly being called in connection with calls for new protectionism. According to China's subsidies distort the (fair) global competition [35].

The exit of the British from the European Union also gives reason to look critically at the potential use of strategic trade policy with regard to free trade outside the EU.

Ultimately, in a juxtaposition of free trade and protectionism is always the all-important question, will the players who have been playing unfairly convince the fair players to cross over to the unfair side, or will the fair players manage to convince the so far unfairly playing parties to finally stick to the rules and play a fair game.

V. CONCLUSION

The current state of research seems to confirm that both the number of compliance regulations and neo-protectionist measures are steadily increasing, making global trade more complex and more difficult month by month. Free trade developed over decades, which has undoubtedly produced prosperity and technical development for many, no longer seems to embody the non plus ultra of modern trade policy.

The further development of compliance shall therefore be observed particularly critically from this point of view.

It's obvious that not all, but a concerning part of typical compliance rules have a protectionist effect and it has to be assumed that this effect is meet with approval by the governmental bodies (and – if applicable - its supervising jurisdiction). This applies most notably for environmental, employment (incl. health & safety) and other rules and regulations tax equity, which are justified with fairness, ethics and moral.

This is how the international trade agreements (GATT; WHO) also proposed from the outset that exceptions to the principle of the free market economy are possible, infringements can be sanctioned with countermeasures and ultimately an equalization of the market conditions should be made possible. Especially the latter aspect is ideally suited for "leading economic nations" to "protection" their own economy and to refer to a positive objective. Who is not against child labor, exploitation, forced labor, environmental destruction, tax evasion or corruption and bribery?

So let's have a look, for example, at China and the state-organized transfer of know-how from there, European and German "protective measures" act as a positive objective. From a German point of view, the same US efforts, especially under former President Donald Trump, were seen and commented as a policy of discrimination and thus negatively.

With new and/or extended "Compliance Rules", the governments therefore have another tool in the "toolbox" to protect their own economy, provided that it generally already complies with the corresponding regulations or at least the resources to implement them in the affected companies are already available.

Depending on the development of global markets, the states can therefore use "Compliance Rules" as part of their strategic trade policy. Especially developing and emerging countries with a less pronounced degree of administrative organization (keyword: "documentation is the be-all and end-all of compliance"), less occupational safety and environmental protection can be taken "out of the game". Take Bulgaria, for example, the implementing of Good Governance and all relevant European regulations still demand significant resources and are described as one of the main tasks and challenges of the Bulgarian government [36]. The fact that NGOs and the left-wing moralists, who themselves have been emerging in the wealthy industrial countries for some time, provide the templates for neo-protectionism with their calls for "fair trade" (but mostly only includes working conditions and environmental protection) is not without a certain irony; but can simply be explained by their perceived moral superiority and their own financial coziness.

Business-close economic lobbyists, just like the governments, then have the difficult task of weighing up the extent to which new compliance rules actually also burden domestic companies additionally and to what extent foreign companies would have an upside or disadvantage as a result.

The current discussion about national and international supply chain law shows exactly this area of tension and remains to be seen for which way the industrialized countries and, of course, Germany and the European Union will position themselves.

REFERENCES

[1] See for example https://www.spiegel.de/sport/fussball/fussball-wm-2006-sommermaerchen-ermittler-finden-brisante-datei-a-1199520.html, last access on 14.03.2021.

[2] https://www.destatis.de/DE/Methoden/WISTA-Wirtschaft-und-Statistik/2007/04/exportweltmeister-deutschland-042007.pdf?__blob=publicationFile, last access on 04.09.2021.

[3] https://www.lto.de/recht/justiz/j/eu-kommission-rechtsstaat-deutschland-justiz-weisung-unabhaengigkeit-ungarn-polen-europa/, last access on 04.09.2021.

[4] For example the „Maskenskandals" (*mask scandal*) within the party CDU in 2021 and the corruption scandal „Aserbaidschan Korruption im Bundestag"; see https://www.spiegel.de/politik/deutschland/cdu-csu-nach-masken-skandal-alle-unionsabgeordneten-unterzeichnen-ehrenerklaerung-a-f6d1943b-76a6-430c-a690-8f50cfdddf12, last access on 14.03.2021.

[5] https://www.welt.de/wirtschaft/karriere/article140421432/Wozu-ist-Compliance-da-wenn-sie-keiner-beachtet.html, last access on 31.08.2021.

[6] Menner/Bexa (2019), Praktische Vorgehensweise bei der Einführung eines Tax Compliance Management System im Unternehmen, CCZ 2019, page 129.

[7] Küttner, Wolfdieter (2020), Personalbuch, 1. Begriff. Rn. 1-2a, beck-online.

[8] Wybitul, Tim, Betriebs Berater (2009), page 606; German Commerzbank had to pay half of its annual profit as penalty to the US authorities, because of violations of the sanctions regulations.

[9] Cohen/Holland, CCZ 2008, page 9.

[10] https://www.justice.gov/archive/opa/pr/2008/September/08-crm-848.html, last access on 19.09.2021.

[11] See for example https://www.spiegel.de/wirtschaft/unternehmen/nach-huawei-usa-koennten-auch-chinesische-ueberwachungsfirmen-sanktionieren-a-1268655.html, zuletzt abgerufen am 24.09.2021 und https://www.spiegel.de/wirtschaft/unternehmen/usa-setzen-huawei-auf-schwarze-liste-a-1267868.html, last access on 22.05.2019.

[12] https://www.welt.de/wirtschaft/article187523506/Weltwirtschaftsforum-Jair-Bolsonaro-verpatzt-seine-Chance-in-Davos.html#cs-lazy-picture-placeholder-01c4eedaca.png, last access on 24.09.2021.

[13] BGH 17.7.09 – 5 StR 394/08, NJW 09, 3173.

[14] Hauschka, Christoph E. ZIP (2004), page 877 and Mengel/Hagemeister Betriebs Berater (2006), page 2466.

[15] https://www.welt.de/wirtschaft/article176390304/Das-Erbe-von-Bilfinger-holt-Roland-Koch-wieder-ein.html, last access on 21.09.2021.

[16] Umnuß, Karsten, (2020), Corporate Compliance Checklisten, Vorwort, C.H. Beck Verlag, München

[17] Reimers/Brack/Schmidt, CCZ 2016, 83.

[18] www.justice.gov/sites/default/files/atr/legacy/2015/04/23/sherman10.pdf , last access on 15.10.2020.

[19] Reimers/Brack/Schmidt, CCZ 2016, 83.

[20] https://www.haufe.de/compliance/recht-politik/hm-akzeptiert-rekordbussgeld-wegen-datenschutzverstoessen_230132_528454.html, last access on 24.09.2021.

[21] See for example http://www.zeit.de/politik/ausland/2018-02/nordkorea-konflikt-usa-sanktionen, last access on 20.03.2018; http://www.faz.net/aktuell/politik/ausland/russland-eu-verlaengert-sanktionen-gegen-putin-und-ukrainer-15489828.html, last access on 20.03.2018; http://www.sueddeutsche.de/politik/usa-und-iran-usa-verschaerfen-sanktionen-gegen-iran-1.3815065, last access on 04.09.2020.

[22] Nymalm, Nicola (2011), Zwischen Liberalisierung und Protektionismus: Wohin steuert die US-Außenhandelspolitik? GIGA Focus Global, Nummer 06.

[23] https://www.nytimes.com/2011/10/20/business/global/us-solar-manufacturers-to-ask-for-duties-on-imports.html., last access on 05.09.2020.

[24] https://www.welt.de/wirtschaft/article174678895/Welthandel-Trumps-Strafzoelle-ergeben-strategisch-Sinn.html, last access on 20.03.2018.

[25] Oppermann, Thomas/Baumann, Julia (1991), Die Ordnung des Welthandels: GATT und regionale Organisationen, page 96.

[26] https://www.zeit.de/2012/15/Globalisierung-Handelskriege, last access on 19.08.2021.

[27] EuGH, ECLI:EU:C:2016:108 = EuZW 2016, page 439.

[28] Wünsche, Horst Friedrich (1984), Protektionismus: Ökonomische Konsequenz einer emanzipierten Technik, page 124.

[29] https://bdi.eu/artikel/news/protektionismus-schadet-wie-staaten-ihre-maerkte-abschotten/, last access on 04.07.2021.

[30] http://www.wirtschaftslexikon24.com/d/strategische-handelspolitik/strategische-handelspolitik.htm, last access on 20.03.2021.

[31] Wünsche, Horst Friedrich (1984), Protektionismus: Ökonomische Konsequenz einer emanzipierten Technik, page 128.

[32] https://www.bmwi.de/Redaktion/DE/Dossier/ttip.html, last access on 02.08.2021; http://www.zeit.de/wirtschaft/unternehmen/2017-06/freihandelsabkommen-ttip-angela-merkel-usa-regierung-eu, last access on 02.08.2021.

[33] See for example https://www.welt.de/wirtschaft/article163921393/US-Finanzminister-stellt-klare-Forderung-an-Schaeuble.html, last access on 02.09.2020.

[34] https://www.welt.de/wirtschaft/video188068879/Industriestrategie-2030-Altmaier-stellt-Deutsche-Bank-und-ThyssenKrupp-unter-Artenschutz.html, last access on 20.07.2021.

[35] https://www.iwkoeln.de/presse/interviews/beitrag/juergen-matthes-chinas-subventionierung-der-industrie-verzerrt-den-weltweiten-wettbewerb.html, last access on 20.07.2021.

[36] Gankova-Ivanova (2012), Verwaltungskapazität, Verwaltungsmodernisierung und E-Government in Bulgarien, Primat des Handels, Festschrift for Walter Maier, Richard Boorberg publishing, page 205.

This page is intentionally left blank

Engineering

Chair: Hristomir Yordanov

This page is intentionally left blank

Application of an Auction based Automotive Power Network Management

Einsatz eines Auktionsbasierten Fahrzeug-Bordnetzmanagements

Tobias Schürmann*, Stefan Schwab*, Sören Hohmann†

*FZI Research Center for Information Technology, Karlsruhe, schuermann@fzi.de
†Karlsruhe Institute of Technology, Institute of Control Systems, Karlsruhe, hohmann@kit.edu

Abstract — Due to the rising complexity and the demanded modularity for the automotive power network (APN), there is a growing need for a distributed and flexible automotive power network management. Recently, we presented a power management which incorporates auction theory in order to achieve distributed decision-making and to ensure scalability and fault tolerance. Thereby, the approach addresses modern APNs with multiple voltage levels and utilizes service-oriented architecture (SOA) for communication. This paper demonstrates the update mechanisms needed to facilitate a plug-and-play integration of new components and the application of customer preferences. We explain the steps regarding startup and update procedures in the SOA which enable the plug-and-play property of the proposed approach. Additionally, the possibility to introduce energy saving strategies is elaborated.

Zusammenfassung — Aufgrund der steigenden Komplexität und der geforderten Modularität von Fahrzeug-Bordnetzen gibt es einen wachsenden Bedarf für ein verteiltes und flexibles Bordnetzmanagment. Ein entsprechendes Bordnetzmanagement wurde kürzlich vom Autor vorgestellt. Dieses Bordnetzmanagement benutzt Auktionstheorie, um damit eine verteilte Entscheidungsfindung zu erreichen und Skalierbarkeit und Fehlertoleranz sicherzustellen. Das Verfahren ist für moderne Fahrzeugbordnetze mit mehreren Spannungsebenen ausgelegt und nutzt eine Service orientierte Archtiktur (SOA) zur Kommunikation. In dieser Arbeit werden die Update Mechanismen dargestellt, die zur Ermöglichung der Plug-and-Play Integration von neuen Komponenten und zur Anwendung von Nutzereinstellungen benötigt werden. Dazu werden die Schritte beim Start und die Vorgehensweise bei einem Update in der SOA erklärt, welche die Plug-and-Play Eigenschaft des Systems gewährleisten. Des Weiteren wird die Möglichkeit zur Integration von Energiesparstrategien beschrieben.

I. Introduction

The growing number of components in the automotive power network (APN) increases the vehicle complexity and confronts manufactures with great challenges [1], [2]. Furthermore, development cycles for software are shortening and the software level needs to be more flexible then ever to meet the need for customization [3]. On the other hand, environmental concerns and cost reduction call for a sustainable and comprehensive development of hardware systems [4]. Hence, update cycles for software and hardware domain are deviating. Additionally, the upgrade of vehicles with new hardware components, for instance regarding autonomous driving, calls for plug-and-play features of new components. The flexibility and modularity in the overall vehicle is guaranteed by a distributed design of the power management system. Therefore, we presented a power management shell (PMS) based on auction theory for modern vehicle topologies [5].

In Fig. 1 an exemplary modern APN with two voltage levels is shown. As a basis, the APN compromises the electric machine (EM) (48V Starter Generator), the energy storages (48V Battery, 12V Battery), the power electronics (PE) (DC/DC), and the wiring harness. For vehicles with (additional) electric propulsion, the loads powered by the APN are divided on the highest level into propulsive (EM) and nonpropulsive loads (48V Electrical Loads, 12V Electrical Loads). Thereby, the APN in Fig. 1 is usually applied to a hybrid electric vehicle (HEV) which uses the EM to boost driving operation and to regenerate energy by recuperation. Depending on the applied EM, the propulsion mostly poses the highest requirements in terms of absolute power consumption and power transients. The nonpropulsive loads differ in critical or safety-relevant components and comfort or hotel components [6]. A further load property for differentiation is the controllability. While some loads are continuously controllable by PE, others may only be switched in discrete steps. For further information about the APN and vehicle topologies we refer to [4].

Fig. 2 gives a simplified overview on the different management level within the control system of the APN [7]. Thereby, the PMS is the mid-level management which is embedded by the energy management shell (EMS) as the top level management and the power electronics shell (PES) on the bottom. The EMS determines the energy flows in the vehicle with respect to the different energy sources. Since the EMS plans the energy strategy, it has
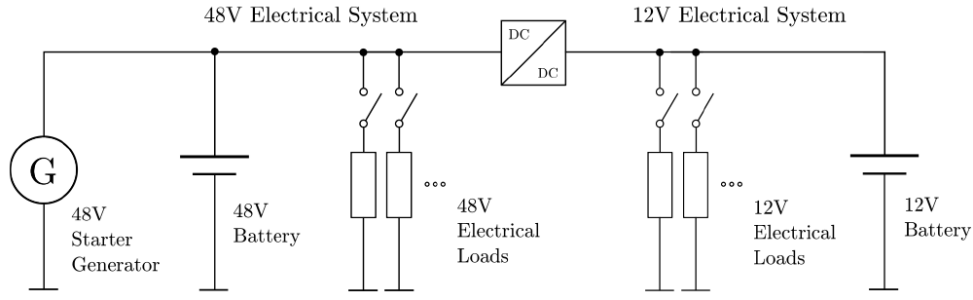
Fig. 1. Modern APN with two voltage levels and various subsystems.

update cycles in the range of seconds. The PMS coordinates the power flows based on the energy strategy and the current availability of power. Hence, the PMS is of high importance in phases of exorbitant power demand. The PES is responsible for the control of the actual power flows and the stabilization of demanded voltage levels.

In the following Section 2, we introduce the proposed power management approach which makes use of SOA as the communication paradigm to facilitate modularity and fault-tolerance [5]. In order to achieve the plug-and-play property, the proposed algorithm for the PMS based on auction theory is extended by an update mechanism. Subsequently, we discuss options for energy saving strategies within the APN and argue the capability of the approach in Section 3.

II. Power Management based on Auction Theory

The proposed algorithm for the PMS is based on the unified pricing auction (UPA) [8] and builds the foundation for the underlying voltage stabilization by the PES (see Fig. 2). A detailed description of the algorithm which extends the initial ideas in [9] and [10] is elaborated in [5]. The basic idea is to calculate the supply and demand in the APN with regard to the current price for power p. Thereby, the price p is determined by the capability of the suppliers, for instance the EM, and the current demand of the power consuming components.

A. Basic Algorithm

To balance the provided and demanded power in the APN, the different components communicate with a central auctioneer which accumulates both sides and calculates the price p for the next time step k (see Fig. 3). The algorithm starts with an initial price p_{init} and is repeated for every time step k with the previous market clearing price $\text{MCP}(k-1)$. For a smooth calculation, the price-to-power functions (PPFs) are designed monotonically increasing for the suppliers and monotonically decreasing for the consumers. Furthermore, for monotonic PPFs, an intersection between supply and consumption is guaranteed

[10]. In case of various voltage levels which is common in modern cars, the dc/dc-converter limitations in terms of power transfer $P_{\text{PE,lim}}$ between the voltage levels $\mathbb{V}$ have to be taken into account. Thus, an individual price adaptation mechanism is needed. If the limit of a PE in the PES is exceeded, the voltage level price p^j in the supplied voltage level $\mathbb{V}_j$ is adapted accordingly. Thereby, the individual sum of supply and consumption in $\mathbb{V}_j$ needs to be calculated. If the sum is below the PE limitation, the individual market price adaption for p^j is terminated. The adjustment for the voltage levels is proceeded until all the PE limitations are met.

The stability and scalability of the suggested auction procedure for the PMS is ensured by the price ranges for the individual design of the PPFs (see Table I). The maximum market price p_{max} is set to 10. Since the market price is expected to be positive, the resulting price range is $p \in [0, 10]$. Table I lists the price intervals and the abstract interpretation regarding the component behavior. The plug-and-play property of the power management algorithm relies on the compliance of these mandatory boundaries.

For Δp_{rec}, the EM is or has recently been in recuperation mode. In order to convert as much kinetic energy as possible, the various systems and comfort components are asked to consume extra power. Thereby, more energy is converted or the battery charging current is reduced which overcomes the limitations of the PE and the battery storages or mitigates the strain on the battery [11]. If the APN is not able to consume or store the provided electric power ($p = 0$), the EM will reduce the recuperation and braking moment is shifted to alternative braking systems. In the optimal range Δp_{opt}, the operation of the subsystems is optimized regarding energy efficiency and comfort of the driver and the passengers. In the following price range Δp_{red}, the components referring to comfort functionalities are demanded to reduce their power consumption. Hence, the power is mainly balanced by demand reduction. The last price range Δp_{crit} depicts the critical APN state. In Δp_{crit}, all comfort systems are switched off and the APN operates in emergency mode. Thus, only safety-relevant systems are supplied which ensures a safe driving operation and the possibility to safely stop the car if necessary.

Fig. 2. Management levels in APNs adapted from [7].

B. Customization of Price-to-Power Functions

The suggested price ranges shape the underlying rules for the individual PPFs. Thereby, every component has its
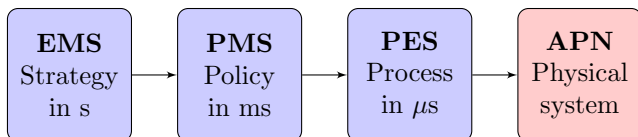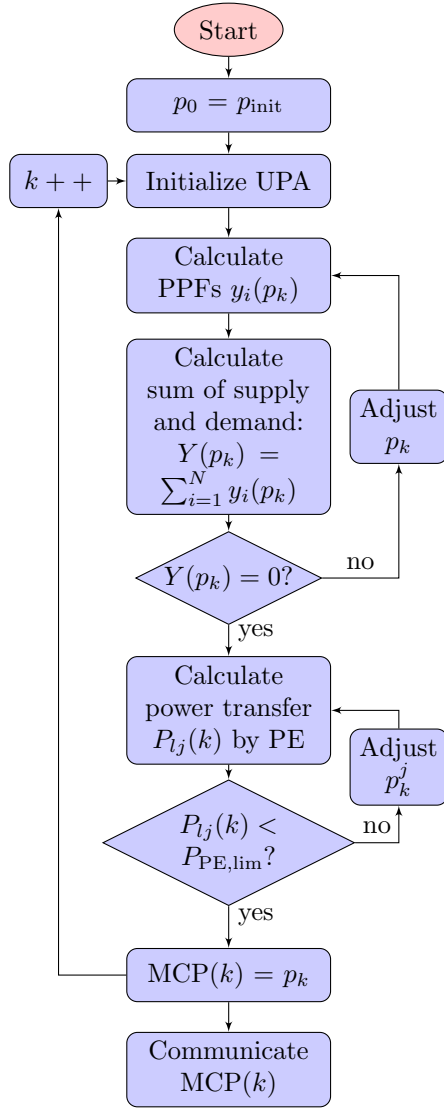
Fig. 3. Modular PMS based on UPA with the adaption for multiple voltage levels $\mathbb{V}_j$ and the consideration of PE limitations $P_{\mathrm{PE,lim}}$.

own PPF which takes into account the individual component states and maybe the driver's or passengers' preferences. However, the price ranges in Table I describe mandatory specifications for every PPF which are important in particular for emergency situations. The plug-and-play feature for new components is ensured by considering these underlying rules in the individual PPF design.

The behavior in certain price levels depends on the general functionality of the component and the user preferences. An example for a PPF of a supplier system in the

TABLE I. PRICE RANGES AND COMPONENT BEHAVIOR AS MANDATORY SPECIFICATIONS FOR THE PPF DESIGN IN ORDER TO ACHIEVE THE PLUG-AND-PLAY PROPERTY OF THE OVERALL ALGORITHM.

Range	Variable	Interpretation
$[0, 2]$	Δp_{rec}	Recuperation mode
$(2, 6]$	Δp_{opt}	Adaptive power supply
$(6, 8]$	Δp_{red}	Reduced comfort
$(8, 10]$	Δp_{crit}	Critical APN status

APN is demonstrated in Fig. 4. Since the battery is a storage system, it acts as supplier or consumer depending on the internal states and the state of the power network. Here, the state of charge (SOC) is the most important state regarding the general functionality. As shown in Fig. 4, the battery PPF accounts for the necessity of charging when the SOC is low and offers power to the APN for a higher SOC. With regard to the boundaries, the battery is only a power supplier (SOC = 1) or a power consumer (SOC = 0), respectively.
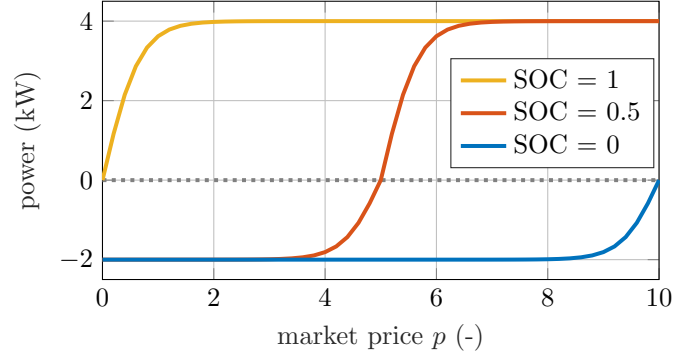

Fig. 4. PPF customization for the battery with different SOC levels.

The seat heating is a comfort component which has a flexible power consumption due to the heat capacity of the seats. If the available power in the APN is restricted, the seat heating could be switched off in order to reduce the consumed power. On the other hand, for recuperation phases, the seat heating is able to consume additional power. Both operations are possible without comfort reduction for the passengers since the heat capacity of the seat prevents the seat temperature from leaving the comfort zone around the set point in the short term. An exemplary design of the seat heating PPF is visualized in Fig. 5. As the seat heating system is a power consumer with discrete power steps, the power control causes more challenges to the auction mechanism [10]. To achieve a smooth market price calculation, the depicted seat heating PPF comprises linear transitions between the discrete power level steps and a hysteresis to prevent iterated switching (see the blue lines in Fig. 5). In general, the exemplary seat heating system consists of three power levels. For the recuperation phase which offers extra power, the highest seat heating level is chosen. The power level of the mid-term market price range refers to the level which is set by the passenger. If the price p exceeds the price limit p_{red}, the power level is reduced.

C. Communication, Startup, and Update Mechanism

The general decision about communication approaches based on SOA for the implementation of the distributed power management is explained in [5]. In this contribution, the event-based communication which collects all the information within the central market place is further elaborated and extended with an update mechanism. With the knowledge about the PPFs and the system states, the central auctioneer has the necessary information to directly calculate the MCP (see Fig. 3).
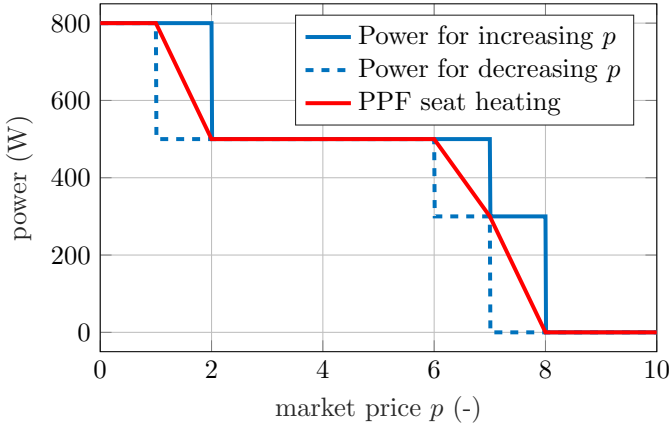
Fig. 5. The seat heating PPF in red and the actual power levels with hysteresis in blue for an increasing p (solid line) and for a decreasing p (dashed line).

For each change regarding the PPFs or the internal states of the components, the central auctioneer has to be informed. Particularly, the internal states need to be updated regularly since they dynamically change during operation. For a smooth behavior in terms of power balancing, the different components with switching behavior, for example seat heating, blowers, or wipers, need to be coordinated. Otherwise, due to the hysteresis, the difference between the calculation for the UPA algorithm and the actual power demand would grow with the number of switching components. Therefore, the price ranges Δp_{rec} and Δp_{red} in which the switching occurs are divided in sections corresponding to the number of power steps. Furthermore, the power difference between the steps could be considered in the update mechanism so that the power reduction is even in the intervals. A major factor in the update process for the sectioning are the user preferences. Thereby, the allocation of the sections correlates with the priority of the components. If a component in the APN is ranked with a higher priority, it will be switched off later and vice versa. Hence, the driver is able to customize the behavior of the power management with regard to the individual preferences. The update mechanism for the hysteresis is performed whenever a component changes its behavior, for instance if a passenger selects a new step for the seat heating. New components in the APN are automatically considered in this procedure.

D. Energy Efficiency and Energy Saving

In general, energy efficiency is a task on the component level. Thereby, the individual component or system in the APN should be designed to fulfill its tasks with a minimum effort regarding communication, computation, and power consumption [4]. As an example, the electrification of the heating ventilation and air conditioning (HVAC) system leads to various improvements in terms of component efficiency and adds flexibility to the APN [11]. Additionally, the electrification enables further possibilities on the system level, for instance the start-stop mechanism which facilitates the vehicle to stop the traction motor(s) in a waiting phase without stopping the HVAC. The utilization of extra energy in phases of recuperation which makes use of the flexible loads is another possibility that is already

considered in the proposed algorithm (see Δp_{rec} in Table I). Here, the prediction of the future driving situation offers further potentials for optimization on component and on system level [11].

However, energy savings make only sense if the driver or passenger preferences are taken into account. Thus, driver and passengers should get useful hints for energy saving settings within the customizable preferences. Whereas, an artificial restriction of power in the APN in order to switch off comfort components which is suggested in [10] only results in dissatisfied customers in the long run.

III. CONCLUSION

Modularity and flexibility are important factors for modern vehicles which are enabled by the proposed power management algorithm based on auction theory [5]. Thereby, we explain the basic algorithm design and the customization in terms of adaptable PPFs which take into account the internal states and the driver preferences. To achieve the plug-and-play feature regarding the inclusion of new components, a suitable startup procedure and an update mechanism for components with switching behavior is elaborated. The update mechanism which allocates the power steps of the switching components for smooth load reduction is applied regularly during operation. Furthermore, we present different strategies for energy efficiency and energy savings which are partly considered in the proposed algorithm or could lead to further improvements.

REFERENCES

[1] P. Mantilla-Perez, J.-A. Perez-Rua, M. A. D. Millan, X. Dominguez, and P. Arboleya, "Power flow simulation in the product development process of modern vehicular dc distribution systems," *IEEE Transactions on Vehicular Technology*, vol. 69, no. 5, pp. 5025–5040, 2020.

[2] T. Isermann, S. Sester, and A. Monti, "A multi-agent based energy management system for electric vehicles," in *2014 IEEE Vehicle Power and Propulsion Conference (VPPC)*. IEEE, 27.10.2014 - 30.10.2014, pp. 1–6.

[3] S. Kugele, P. Obergfell, M. Broy, O. Creighton, M. Traub, and W. Hopfensitz, "On service-orientation for automotive software," in *ICSA 2017*, I. I. C. o. S. Architecture, Ed. Piscataway, NJ: IEEE, 2017.

[4] M. Ehsani, Y. Gao, S. Longo, and K. Ebrahimi, *Modern electric, hybrid electric, and fuel cell vehicles: Fundamentals, theory, and design*. Boca Raton: CRC Press, 2018.

[5] T. Schuermann, A. Rafles, S. Schwab, and S. Hohmann, "Distributed and modular automotive power network management based on auction theory," 2021 - In Publication.

[6] Luk and Rosario, "Towards a negotiation-based multi-agent power management system for electric vehicles," in *2005 International Conference on Machine Learning and Cybernetics*. IEEE, 21.08.2005 - 21.08.2005, pp. 410–416.

[7] L. Rosario and P. C. K. Luk, "Applying management methodology to electric vehicles with multiple energy storage systems," in *2007 International Conference on Machine Learning and Cybernetics*. IEEE, 19.08.2007 - 22.08.2007, pp. 4223–4230.

[8] S. Nojavan and K. Zare, *Electricity Markets: New Players and Pricing Uncertainties*. Springer International Publishing, 2020.

[9] H.-M. Graf, "Verfahren zur Steuerung der Energieverteilung in einem Verkehrsmittel und Verkehrsmittel, das dieses Verfahren umsetzt," Patent DE10 252 292A1, 2004.

[10] S. Büchner, *Energiemanagement-Strategien für elektrische Energiebordnetze in Kraftfahrzeugen*. Cuvillier Verlag, 2008.

[11] K. Vatanparvar and M. A. Al Faruque, "Battery lifetime-aware automotive climate control for electric vehicles," in *Proceedings of the 52nd Annual Design Automation Conference*. New York, NY, USA: ACM, 06072015, pp. 1–6.

Explicit Port-Hamiltonian Representation of Feedthrough-Systems with Nonlinear Dissipation

Explizite Port-Hamiltonsche Darstellung von Durchgriffsystemen mit nichtlinearer Dissipation

Martin Pfeifer*, Mathias Kluwe* and Sören Hohmann*

*Karlsruhe Institute of Technology (KIT), Institute of Control Systems (IRS),
Kaiserstr. 12, 76131 Karlsruhe, Germany, e-mail: {martin.pfeifer, mathias.kluwe, soeren.hohmann}@kit.edu

Abstract — In this technical note, we present an explicit port-Hamiltonian formulation of feedthrough-systems subject to nonlinear energy-dissipating effects. To this end, we merge the Dirac structure—which describes the system's internal interconnection structure—with the constitutive relations of energy-storing and energy-dissipating elements. The resulting port-Hamiltonian system (PHS) is proven to be passive and generalizes an existing nonlinear-dissipative port-Hamiltonian formulation from the literature by feedthrough.

Zusammenfassung — In diesem Beitrag wird eine explizite Port-Hamiltonsche Formulierung von Durchgriffsystemen mit nichtlinear-dissipativen Effekten vorgestellt. Die Herleitung der Systemgleichungen erfolgt durch die Zusammenführung der Dirac-Struktur des Systems und den Konstitutiv-Gleichungen der energiespeichernden und energiedissipierenden Systemelemente. Die Passivität des vorgestellten Port-Hamiltonschen Systems (PHS) wird mathematisch nachgewiesen. Ferner zeigt sich, dass die Systemformulierung eine Verallgemeinerung eines aus der Literatur bekannten nichtlinear-dissipativen PHS darstellt.

I. Introduction

Port-Hamiltonian systems (PHSs) are a powerful framework for developing control systems for complex physical systems. PHSs have first been introduced for real-valued, continuous-time nonlinear systems with lumped parameters (see, e.g., [1, 2]). Meanwhile, the port-Hamiltonian framework has been extended to complex-valued systems (see, e.g., [3]), discrete-time systems (see, e.g., [4]), and distributed-parameter systems (see, e.g., [5, 6]).

Port-Hamiltonian methods have three advantages over standard state-space approaches: Firstly, they are based on energy as domain-independent conserved quantity. This enables to treat multi-domain systems in a unifying methodological framework. Secondly, PHSs are passive in consequence of their system formulation. Therewith, they provide an ideal basis for the powerful methods from passivity-based nonlinear control. Thirdly, port-Hamiltonian methods are highly modular and scalable to large systems. Due to these three reasons, PHSs are of great interest when developing control systems for nonlinear mechatronic systems, see [7, pp. 131ff.].

Port-Hamiltonian control design methods are model-based. The majority of methods is based on an explicit port-Hamiltonian model, i.e., a PHS in form of an ordinary differential equation (ODE), see, e.g., [8], [9], [10]. For systems with energy-dissipating elements that are linear (e.g., Ohm's law), there exist well known explicit port-Hamiltonian representations. This applies to both, systems with and without feedthrough, see, e.g., [7, pp. 70–71]. For the case of nonlinear energy-dissipation (e.g., systems with

nonlinear friction), the situation is different. Indeed, the author of [9, p. 114] proposes a port-Hamiltonian representation for such systems without feedthrough. However, as of now, there has been no reports on a port-Hamiltonian ODE representation of systems with nonlinear energy dissipation and feedthrough.

In this contribution, we bridge this research gap. We propose an explicit port-Hamiltonian representation for systems with nonlinear energy-dissipating effects and feedthrough. Passivity of the port-Hamiltonian representation is proven. Moreover, we show that our representation is a generalization of the PHS proposed in [9, p. 114].

Notation: Sets and spaces are written in blackboard bold. The set $\mathbb{R}$ is the set of real numbers. Vectors and matrices are written in bold font. Let $\boldsymbol{A} \in \mathbb{R}^{m \times n}$ be a matrix with m rows and n columns. For the transpose of $\boldsymbol{A}$ we write $\boldsymbol{A}^\top$. Consider a continuously differentiable function $f \colon \mathbb{R}^n \to \mathbb{R}$, $\boldsymbol{x} \mapsto f(\boldsymbol{x})$. We call f non-negative if $f(\boldsymbol{x}) \geq 0$ for all $\boldsymbol{x} \in \mathbb{R}^n$.

Throughout this paper, the time-dependence "(t)" of vectors is omitted in the notation.

II. Problem Statement

We consider a physical system being composed of N_C energy-storing elements, N_R energy-dissipating elements, and N_P energy sources.[1] The total number of system elements is given by $N_\mathrm{E} = N_\mathrm{C} + N_\mathrm{R} + N_\mathrm{P}$. Each system element is equipped with a so-called power port to interact with the other system elements. A power port is de-

---

[1] Energy sinks can be seen as negative energy sources.

scribed by an input variable u_i and an output variable y_i, $i = 1, \ldots, N_{\mathrm{E}}$.

Fig. 1 depicts an exemplary system with one energy-storing element C_1, two energy-dissipating elements R_1 and R_2, and one source of energy P_1. The half arrows—so-called *bonds* [7, pp. 4ff.]—symbolize an exchange of power through the elements' ports. The direction of a bond determines the positive direction of the associated power flow.
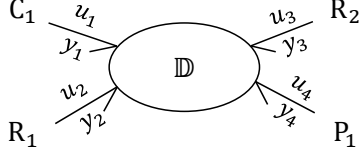

Fig. 1. Illustrative example system with $N_{\mathrm{C}} = 1$, $N_{\mathrm{R}} = 2$, and $N_{\mathrm{P}} = 1$

The input variables of the storage elements, dissipating elements, and source elements are collected in the vectors $\boldsymbol{u}_{\mathrm{C}} \in \mathbb{R}^{N_{\mathrm{C}}}$, $\boldsymbol{u}_{\mathrm{R}} \in \mathbb{R}^{N_{\mathrm{R}}}$, and $\boldsymbol{u}_{\mathrm{P}} \in \mathbb{R}^{N_{\mathrm{P}}}$, respectively; the output variables are summarized in the vectors $\boldsymbol{y}_{\mathrm{C}} \in \mathbb{R}^{N_{\mathrm{C}}}$, $\boldsymbol{y}_{\mathrm{R}} \in \mathbb{R}^{N_{\mathrm{R}}}$, and $\boldsymbol{y}_{\mathrm{P}} \in \mathbb{R}^{N_{\mathrm{P}}}$, respectively.

Let the constitutive relations of the energy-storing elements be given as:

$$\boldsymbol{y}_{\mathrm{C}} = -\dot{\boldsymbol{x}}, \qquad \boldsymbol{u}_{\mathrm{C}} = \frac{\partial H}{\partial \boldsymbol{x}}(\boldsymbol{x}), \qquad (1)$$

where $\boldsymbol{x} \in \mathbb{X} \subseteq \mathbb{R}^{N_{\mathrm{C}}}$ is the energy state and $H \colon \mathbb{X} \to \mathbb{R}$ is a differentiable storage function that is bounded from below. For the energy-dissipating elements, we suppose nonlinear constitutive relations which are expressed as the graph of an input-output map:

$$\boldsymbol{u}_{\mathrm{R}} = \boldsymbol{\Phi}(\boldsymbol{y}_{\mathrm{R}}, \boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u}_{\mathrm{P}}), \qquad (2)$$

where $\boldsymbol{y}_{\mathrm{R}}^{\top} \boldsymbol{u}_{\mathrm{R}} \leq 0$. In (2), $\boldsymbol{z} := \frac{\partial H}{\partial \boldsymbol{x}}(\boldsymbol{x})$ is the co-state of the system.

The interconnection of the system elements is described by a modulated Dirac structure, see Fig. 1. A Dirac structure is a power-conserving, geometric structure which describes the interconnection between the system elements. A detailed introduction into the concept of Dirac structures can be found in [7] and [11]. We suppose a Dirac structure in input-output representation [7, p. 87] in which the inputs are mapped to the outputs:

$$\mathbb{D}(\boldsymbol{x}) = \{(\begin{pmatrix} \boldsymbol{u}_{\mathrm{C}} \\ \boldsymbol{u}_{\mathrm{R}} \\ \boldsymbol{u}_{\mathrm{P}} \end{pmatrix}, \begin{pmatrix} \boldsymbol{y}_{\mathrm{C}} \\ \boldsymbol{y}_{\mathrm{R}} \\ \boldsymbol{y}_{\mathrm{P}} \end{pmatrix}) \in \mathbb{R}^{N_{\mathrm{E}}} \times \mathbb{R}^{N_{\mathrm{E}}} \mid$$

$$\begin{pmatrix} \boldsymbol{y}_{\mathrm{C}} \\ \boldsymbol{y}_{\mathrm{R}} \\ \boldsymbol{y}_{\mathrm{P}} \end{pmatrix} = \underbrace{\begin{pmatrix} \boldsymbol{Z}_{\mathrm{CC}}(\boldsymbol{x}) & -\boldsymbol{Z}_{\mathrm{CR}}(\boldsymbol{x}) & -\boldsymbol{Z}_{\mathrm{CP}}(\boldsymbol{x}) \\ \boldsymbol{Z}_{\mathrm{CR}}^{\top}(\boldsymbol{x}) & \boldsymbol{Z}_{\mathrm{RR}}(\boldsymbol{x}) & -\boldsymbol{Z}_{\mathrm{RP}}(\boldsymbol{x}) \\ \boldsymbol{Z}_{\mathrm{CP}}^{\top}(\boldsymbol{x}) & \boldsymbol{Z}_{\mathrm{RP}}^{\top}(\boldsymbol{x}) & \boldsymbol{Z}_{\mathrm{PP}}(\boldsymbol{x}) \end{pmatrix}}_{\boldsymbol{Z}(\boldsymbol{x})} \begin{pmatrix} \boldsymbol{u}_{\mathrm{C}} \\ \boldsymbol{u}_{\mathrm{R}} \\ \boldsymbol{u}_{\mathrm{P}} \end{pmatrix}\},$$

$$(3)$$

where $\boldsymbol{Z}(\boldsymbol{x}) = -\boldsymbol{Z}^{\top}(\boldsymbol{x}) \in \mathbb{R}^{N_{\mathrm{E}} \times N_{\mathrm{E}}}$ for all $\boldsymbol{x} \in \mathbb{X}$.

The problem to be addressed in this paper now reads:

Problem 2.1. *Given a system described by (1), (2), and (3). What is an explicit port-Hamiltonian formulation of this system in case of feedthrough?*

Remark 2.2. *The input and output variables usually represent generalized efforts and flows. These generalized power variables allow for correspondences in various physical domains, see, e.g., [7, p. 23]. For example, in the electrical domain, the effort corresponds to a voltage and the flow corresponds to a current; in the mechanical domain the effort and flow may be related to a velocity and a force, respectively. Therewith, the product between input and output variables has the unit of power.*

Remark 2.3. *Equations (1) and (2) are well-known standard representations for the constitutive relations of nonlinear energy-storing and energy-dissipating elements, see [12, p. 357] and [11, p. 24], respectively. Moreover, for many systems, a Dirac structure in the form (3) can be computed in an automated manner, see [13, 14].*

Remark 2.4. *The power balance of (3) is*

$$\begin{pmatrix} \boldsymbol{u}_{\mathrm{C}}^{\top} & \boldsymbol{u}_{\mathrm{R}}^{\top} & \boldsymbol{u}_{\mathrm{P}}^{\top} \end{pmatrix} \begin{pmatrix} \boldsymbol{y}_{\mathrm{C}} \\ \boldsymbol{y}_{\mathrm{R}} \\ \boldsymbol{y}_{\mathrm{P}} \end{pmatrix} =$$

$$\begin{pmatrix} \boldsymbol{u}_{\mathrm{C}}^{\top} & \boldsymbol{u}_{\mathrm{R}}^{\top} & \boldsymbol{u}_{\mathrm{P}}^{\top} \end{pmatrix} \boldsymbol{Z}(\boldsymbol{x}) \begin{pmatrix} \boldsymbol{u}_{\mathrm{C}} \\ \boldsymbol{u}_{\mathrm{R}} \\ \boldsymbol{u}_{\mathrm{P}} \end{pmatrix} = 0, \quad (4)$$

where the last equality follows from the skew-symmetry of $\boldsymbol{Z}(\boldsymbol{x})$. Equation (4) shows that the total power entering the Dirac structure is zero, i.e., the power-conservation of the Dirac structure.

In the following section, we present and prove our main results regarding Problem 2.1.

III. MAIN RESULTS

Before we state the main results of this paper, we make the following assumption to exclude interdependencies between energy-dissipating elements:

Assumption 3.1. *In (3), we have $\boldsymbol{Z}_{\mathrm{RR}}(\boldsymbol{x}) = \boldsymbol{0}$ for all $\boldsymbol{x} \in \mathbb{X}$.*

Now for the first main result of this paper:

Proposition 3.2. *Consider a system with constitutive relations of storage elements and dissipative elements in the forms (1) and (2), respectively. Moreover, let the interconnection structure of the system be given as a Dirac structure (3) which satisfies Assumption 3.1.*

Equations (1), (2), and (3) can be written as an explicit input-state-output PHS of the form

$$\dot{\boldsymbol{x}} = \boldsymbol{J}(\boldsymbol{x})\boldsymbol{z} - \boldsymbol{\mathcal{R}}(\boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u}) + \boldsymbol{G}(\boldsymbol{x})\boldsymbol{u}, \qquad (5a)$$

$$\boldsymbol{y} = \boldsymbol{G}^{\top}(\boldsymbol{x})\boldsymbol{z} + \boldsymbol{\mathcal{P}}(\boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u}) + \boldsymbol{M}(\boldsymbol{x})\boldsymbol{u}, \qquad (5b)$$

with vectors $\boldsymbol{x} \in \mathbb{X} \subseteq \mathbb{R}^n$, $\boldsymbol{z} \in \mathbb{Z} \subseteq \mathbb{R}^n$, $\boldsymbol{u} \in \mathbb{U} \subseteq \mathbb{R}^p$, mappings $\boldsymbol{\mathcal{R}}(\boldsymbol{x}, \cdot, \cdot) \colon \mathbb{R}^n \to \mathbb{R}^n$, $\boldsymbol{\mathcal{P}}(\boldsymbol{x}, \cdot, \cdot) \colon \mathbb{R}^n \to \mathbb{R}^p$, and $\boldsymbol{u} = \boldsymbol{u}_{\mathrm{P}}$, $\boldsymbol{y} = \boldsymbol{y}_{\mathrm{P}}$.[2] The dimensions n and p are given as $n = N_{\mathrm{C}}$ and $p = N_{\mathrm{P}}$. In (5), the matrices and mappings satisfy $\boldsymbol{J}(\boldsymbol{x}) = -\boldsymbol{J}^{\top}(\boldsymbol{x})$, $\boldsymbol{M}(\boldsymbol{x}) = -\boldsymbol{M}^{\top}(\boldsymbol{x})$, and

$$\begin{pmatrix} \boldsymbol{z} \\ \boldsymbol{u} \end{pmatrix}^{\top} \begin{pmatrix} \boldsymbol{\mathcal{R}}(\boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u}) & \boldsymbol{0} \\ 0 & \boldsymbol{\mathcal{P}}(\boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u}) \end{pmatrix} \geq 0, \qquad (6)$$

_____

[2]By $\mathbb{Z}$ we denote the real-valued co-state-space. In particular, we do not refer to the set of integers.

for all $\boldsymbol{x} \in \mathbb{X}$, $\boldsymbol{z} \in \mathbb{Z}$, and $\boldsymbol{u} \in \mathbb{U}$. *The matrices can be obtained from* $\boldsymbol{J}(\boldsymbol{x}) = -\boldsymbol{Z}_{\mathrm{CC}}(\boldsymbol{x})$, $\boldsymbol{G}(\boldsymbol{x}) = \boldsymbol{Z}_{\mathrm{CP}}(\boldsymbol{x})$, *and* $\boldsymbol{M}(\boldsymbol{x}) = \boldsymbol{Z}_{\mathrm{PP}}(\boldsymbol{x})$; *the mappings are calculated as*

$$\boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}) = -\boldsymbol{Z}_{\mathrm{CR}}(\boldsymbol{x})\,\boldsymbol{\Phi}\big(\boldsymbol{Z}_{\mathrm{CR}}^{\top}(\boldsymbol{x})\,\boldsymbol{z} - \boldsymbol{Z}_{\mathrm{CP}}(\boldsymbol{x})\,\boldsymbol{u}, \boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u}\big),$$
$$\text{(7a)}$$

$$\boldsymbol{\mathcal{P}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}) = \boldsymbol{Z}_{\mathrm{RP}}^{\top}(\boldsymbol{x})\,\boldsymbol{\Phi}\big(\boldsymbol{Z}_{\mathrm{CR}}^{\top}(\boldsymbol{x})\,\boldsymbol{z} - \boldsymbol{Z}_{\mathrm{CP}}(\boldsymbol{x})\,\boldsymbol{u}, \boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u}\big).$$
$$\text{(7b)}$$

Proof. Inserting $\boldsymbol{u}_{\mathrm{C}} = \boldsymbol{z}$ and (2) into the first line of the equation system from (3) yields

$$\boldsymbol{y}_{\mathrm{C}} = \boldsymbol{Z}_{\mathrm{CC}}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{C}} - \boldsymbol{Z}_{\mathrm{CR}}(\boldsymbol{x})\,\boldsymbol{\Phi}(\boldsymbol{y}_{\mathrm{R}}, \boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u}_{\mathrm{P}}) - \boldsymbol{Z}_{\mathrm{CP}}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{P}}.$$
$$\text{(8)}$$

For the second term of the right side we write

$$-\boldsymbol{Z}_{\mathrm{CR}}(\boldsymbol{x})\,\boldsymbol{\Phi}(\boldsymbol{y}_{\mathrm{R}}, \boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u}_{\mathrm{P}})$$
$$\stackrel{(2)}{=} \underbrace{-\boldsymbol{Z}_{\mathrm{CR}}(\boldsymbol{x})\,\boldsymbol{\Phi}\big(\boldsymbol{Z}_{\mathrm{CR}}^{\top}(\boldsymbol{x})\,\boldsymbol{z} - \boldsymbol{Z}_{\mathrm{CP}}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{P}}, \boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u}_{\mathrm{P}}\big)}_{=\boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}_{\mathrm{P}})}. \quad \text{(9)}$$

By inserting (9) into (8) we obtain (5a):

$$\boldsymbol{y}_{\mathrm{C}} = \boldsymbol{Z}_{\mathrm{CC}}(\boldsymbol{x})\,\boldsymbol{z} + \boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}_{\mathrm{P}}) - \boldsymbol{Z}_{\mathrm{CP}}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{P}}$$

$$\stackrel{(1)}{\Leftrightarrow} -\dot{\boldsymbol{x}} = \boldsymbol{Z}_{\mathrm{CC}}(\boldsymbol{x})\,\boldsymbol{z} + \boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}_{\mathrm{P}}) - \boldsymbol{Z}_{\mathrm{CP}}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{P}}$$

$$\Leftrightarrow \dot{\boldsymbol{x}} = \underbrace{-\boldsymbol{Z}_{\mathrm{CC}}(\boldsymbol{x})}_{=\boldsymbol{J}(\boldsymbol{x})}\boldsymbol{z} - \boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}_{\mathrm{P}}) + \underbrace{\boldsymbol{Z}_{\mathrm{CP}}(\boldsymbol{x})}_{=\boldsymbol{G}(\boldsymbol{x})}\underbrace{\boldsymbol{u}_{\mathrm{P}}}_{=\boldsymbol{u}}.$$
$$\text{(10)}$$

Now for the output equation. From the third line of the equation system in (3) and with $\boldsymbol{u} = \boldsymbol{u}_{\mathrm{P}}$, $\boldsymbol{y} = \boldsymbol{y}_{\mathrm{P}}$ we obtain

$$\boldsymbol{y} = \underbrace{\boldsymbol{Z}_{\mathrm{CP}}^{\top}(\boldsymbol{x})}_{=\boldsymbol{G}^{\top}(\boldsymbol{x})}\boldsymbol{z} + \boldsymbol{Z}_{\mathrm{RP}}^{\top}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{R}} + \underbrace{\boldsymbol{Z}_{\mathrm{PP}}^{\top}(\boldsymbol{x})}_{=\boldsymbol{M}(\boldsymbol{x})}\boldsymbol{u}. \quad \text{(11)}$$

For the second term from the right side we write

$$\boldsymbol{Z}_{\mathrm{RP}}^{\top}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{R}} \stackrel{(2)}{=} \boldsymbol{Z}_{\mathrm{RP}}^{\top}(\boldsymbol{x})\,\boldsymbol{\Phi}(\boldsymbol{y}_{\mathrm{R}}, \boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u})$$
$$\stackrel{(3)}{=} \underbrace{\boldsymbol{Z}_{\mathrm{RP}}^{\top}(\boldsymbol{x})\,\boldsymbol{\Phi}\big(\boldsymbol{Z}_{\mathrm{CR}}^{\top}(\boldsymbol{x})\,\boldsymbol{z} - \boldsymbol{Z}_{\mathrm{CP}}(\boldsymbol{x})\,\boldsymbol{u}, \boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u}\big)}_{=\boldsymbol{\mathcal{P}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u})}. \quad \text{(12)}$$

Inserting (12) into (11) yields (5b).

Next, we show that (6) holds. By multiplying (5a) from the right side with $\boldsymbol{z}^{\top}$ we obtain

$$\boldsymbol{z}^{\top}\dot{\boldsymbol{x}} = -\boldsymbol{z}^{\top}\boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}) + \boldsymbol{z}^{\top}\boldsymbol{G}(\boldsymbol{x})\,\boldsymbol{u}. \quad \text{(13)}$$

On the other hand, by the power balance (4) of the Dirac structure we have

$$\boldsymbol{z}^{\top}\dot{\boldsymbol{x}} \stackrel{(1)}{=} -\boldsymbol{u}_{\mathrm{C}}^{\top}\boldsymbol{y}_{\mathrm{C}} \stackrel{(4)}{=} \boldsymbol{u}_{\mathrm{R}}^{\top}\boldsymbol{y}_{\mathrm{R}} + \boldsymbol{u}_{\mathrm{P}}^{\top}\boldsymbol{y}_{\mathrm{P}}. \quad \text{(14)}$$

Equating (13) and (14) yields

$$-\boldsymbol{z}^{\top}\boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}) + \boldsymbol{z}^{\top}\boldsymbol{G}(\boldsymbol{x})\,\boldsymbol{u} = \boldsymbol{u}_{\mathrm{R}}^{\top}\boldsymbol{y}_{\mathrm{R}} + \boldsymbol{u}_{\mathrm{P}}^{\top}\boldsymbol{y}_{\mathrm{P}}. \quad \text{(15)}$$

The last term reads

$$\boldsymbol{u}_{\mathrm{P}}^{\top}\boldsymbol{y}_{\mathrm{P}} \stackrel{(3)}{=} \boldsymbol{u}_{\mathrm{P}}^{\top}\big(\boldsymbol{Z}_{\mathrm{CP}}^{\top}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{C}} + \boldsymbol{Z}_{\mathrm{RP}}^{\top}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{R}} + \boldsymbol{Z}_{\mathrm{PP}}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{P}}\big)$$

$$= \boldsymbol{u}_{\mathrm{P}}^{\top}\boldsymbol{Z}_{\mathrm{CP}}^{\top}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{C}} + \boldsymbol{u}_{\mathrm{P}}^{\top}\boldsymbol{Z}_{\mathrm{RP}}^{\top}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{R}}$$

$$\stackrel{(2)}{=} \boldsymbol{u}_{\mathrm{P}}^{\top}\boldsymbol{Z}_{\mathrm{CP}}^{\top}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{C}} + \boldsymbol{u}_{\mathrm{P}}^{\top}\boldsymbol{Z}_{\mathrm{RP}}^{\top}(\boldsymbol{x})\,\boldsymbol{\Phi}(\boldsymbol{y}_{\mathrm{R}}, \boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u})$$

$$\stackrel{(3)}{=} \boldsymbol{u}_{\mathrm{P}}^{\top}\boldsymbol{Z}_{\mathrm{CP}}^{\top}(\boldsymbol{x})\,\boldsymbol{u}_{\mathrm{C}}$$
$$+ \boldsymbol{u}_{\mathrm{P}}^{\top}\boldsymbol{Z}_{\mathrm{RP}}^{\top}(\boldsymbol{x})\,\boldsymbol{\Phi}\big(\boldsymbol{Z}_{\mathrm{CR}}^{\top}(\boldsymbol{x})\,\boldsymbol{z} - \boldsymbol{Z}_{\mathrm{CP}}(\boldsymbol{x})\,\boldsymbol{u}, \boldsymbol{x}, \boldsymbol{z}, \boldsymbol{u}\big).$$
$$\text{(16)}$$

With (7a) and $\boldsymbol{u} = \boldsymbol{u}_{\mathrm{P}}$, $\boldsymbol{y} = \boldsymbol{y}_{\mathrm{P}}$ we write (16) as

$$\boldsymbol{u}_{\mathrm{P}}^{\top}\boldsymbol{y}_{\mathrm{P}} = \boldsymbol{u}^{\top}\underbrace{\boldsymbol{Z}_{\mathrm{CP}}^{\top}(\boldsymbol{x})}_{=\boldsymbol{G}^{\top}(\boldsymbol{x})}\boldsymbol{z} + \boldsymbol{u}^{\top}\boldsymbol{\mathcal{P}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}). \quad \text{(17)}$$

By inserting (17) into (15) we prove (6):

$$-\boldsymbol{z}^{\top}\boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}) - \boldsymbol{u}^{\top}\boldsymbol{\mathcal{P}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}) = \boldsymbol{u}_{\mathrm{R}}^{\top}\boldsymbol{y}_{\mathrm{R}} \stackrel{(2)}{\leq} 0. \quad \text{(18)}$$
$$\square$$

To the best of our knowledge, the explicit PHS (5) has not been presented in the literature so far. The next proposition shows that this PHS is passive.

Proposition 3.3. *The PHS* (5) *is passive.*

Proof. Recall $\boldsymbol{z} = \frac{\partial H}{\partial \boldsymbol{x}}(\boldsymbol{x})$ with $H(\boldsymbol{x})$ as a storage function that is bounded from below. We always find a constant $c \in \mathbb{R}_{\geq 0}$ such that $\tilde{H}(\boldsymbol{x}) = H(\boldsymbol{x}) + c$ is a non-negative function. The time derivative of $\tilde{H}(\boldsymbol{x})$ reads

$$\dot{\tilde{H}}(\boldsymbol{x}) = \left(\frac{\partial \tilde{H}}{\partial \boldsymbol{x}}(\boldsymbol{x})\right)^{\top}\dot{\boldsymbol{x}} = \left(\frac{\partial H}{\partial \boldsymbol{x}}(\boldsymbol{x})\right)^{\top}\dot{\boldsymbol{x}}$$
$$= \boldsymbol{z}^{\top}(\boldsymbol{J}(\boldsymbol{x})\,\boldsymbol{z} - \boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}) + \boldsymbol{G}(\boldsymbol{x})\,\boldsymbol{u})$$
$$= -\boldsymbol{z}^{\top}\boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}) + \boldsymbol{z}^{\top}\boldsymbol{G}(\boldsymbol{x})\,\boldsymbol{u}. \quad \text{(19)}$$

Transposing (5b) and multiplying with $\boldsymbol{u}$ from the right gives

$$\boldsymbol{y}^{\top}\boldsymbol{u} = \boldsymbol{z}^{\top}\boldsymbol{G}(\boldsymbol{x})\,\boldsymbol{u} + \boldsymbol{\mathcal{P}}^{\top}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u})\,\boldsymbol{u}$$
$$\Leftrightarrow \boldsymbol{z}^{\top}\boldsymbol{G}(\boldsymbol{x})\,\boldsymbol{u} = \boldsymbol{y}^{\top}\boldsymbol{u} - \boldsymbol{u}^{\top}\boldsymbol{\mathcal{P}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}). \quad \text{(20)}$$

Inserting (20) into (19) then yields

$$\dot{\tilde{H}}(\boldsymbol{x}) = -\boldsymbol{z}^{\top}\boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}) + \boldsymbol{y}^{\top}\boldsymbol{u} - \boldsymbol{u}^{\top}\boldsymbol{\mathcal{P}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u})$$
$$= \boldsymbol{y}^{\top}\boldsymbol{u} - \underbrace{\begin{pmatrix}\boldsymbol{z}\\\boldsymbol{u}\end{pmatrix}^{\top}\begin{pmatrix}\boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}) & \boldsymbol{0}\\0 & \boldsymbol{\mathcal{P}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u})\end{pmatrix}}_{\geq 0} \leq \boldsymbol{y}^{\top}\boldsymbol{u}.$$
$$\text{(21)}$$
$$\square$$

For the case of no feedthrough, we obtain from Proposition 3.2 the "input-state-output PHS with nonlinear resistive structure" introduced by [9, Def. 6.1.4]. This special case is outlined in the subsequent corollary.

Corollary 3.4. *Given an explicit Dirac structure* (3) *which satisfies Assumption 3.1. Let* $\boldsymbol{Z}_{\mathrm{RP}}(\boldsymbol{x}) = 0$ *and* $\boldsymbol{Z}_{\mathrm{PP}}(\boldsymbol{x}) = 0$ *for all* $\boldsymbol{x} \in \mathbb{X}$. *Equations* (1), (2), *and* (3) *can be written as an explicit input-state-output PHS of the form*

$$\dot{\boldsymbol{x}} = \boldsymbol{J}(\boldsymbol{x})\,\boldsymbol{z} - \boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}) + \boldsymbol{G}(\boldsymbol{x})\,\boldsymbol{u}, \quad \text{(22a)}$$
$$\boldsymbol{y} = \boldsymbol{G}^{\top}(\boldsymbol{x})\,\boldsymbol{z}, \quad \text{(22b)}$$

where $\boldsymbol{J}(\boldsymbol{x}) = -\boldsymbol{J}^{\top}(\boldsymbol{x})$ *and* $\boldsymbol{z}^{\top}\boldsymbol{\mathcal{R}}(\boldsymbol{x},\boldsymbol{z},\boldsymbol{u}) \geq 0$ *for all* $\boldsymbol{x} \in \mathbb{X}$, $\boldsymbol{z} \in \mathbb{Z}$, $\boldsymbol{u} \in \mathbb{U}$.

Proof. The proof follows directly from Proposition 3.2 under $\boldsymbol{Z}_{\mathrm{RP}}(\boldsymbol{x}) = 0$ and $\boldsymbol{Z}_{\mathrm{PP}}(\boldsymbol{x}) = 0$. $\square$

The results from Proposition 3.2, Proposition 3.3, and Corollary 3.4 are now discussed in the following section.

IV. Discussion

Equation (5) represents an explicit PHS for systems with nonlinear energy-dissipation and feedthrough. The matrices, functions, and vectors in (5) allow for a deep physical insight as they reflect the physical structure of the underlying system. The state $\boldsymbol{x}$ of the system contains the states of the storage elements. The vector $\boldsymbol{z}$ is the co-state of the system and is given by $\boldsymbol{z} = \frac{\partial H}{\partial \boldsymbol{x}}(\boldsymbol{x})$, where the Hamiltonian H is a storage function which describes the total energy contained in the system. The input $\boldsymbol{u}$ and the output $\boldsymbol{y}$ contain the input and output variables, respectively, of the ports of the energy sources. Therewith, the instantaneous power exchange between the system and its environment is given by $\boldsymbol{u}^\top \boldsymbol{y}$. The skew-symmetric matrix $\boldsymbol{J}(\boldsymbol{x})$ represents the internal energy-preserving interconnection in the system. The functions $\boldsymbol{\mathcal{R}}$ and $\boldsymbol{\mathcal{P}}$ account for energy-dissipating effects. In presence of nonlinear energy-dissipating effects, these functions will be also nonlinear. The matrix $\boldsymbol{G}(\boldsymbol{x})$ specifies the interaction between the system and its environment via the system ports. Finally, the matrix $\boldsymbol{M}(\boldsymbol{x})$ is the feedthrough matrix.

The PHS (5) is passive in consequence of its formulation (see Proposition 3.3). Therewith, this formulation is an ideal basis for applying the powerful methods from passivity-based control. For the case of no feedthrough, the system (5) simplifies to the well-known PHS from [9, Def. 6.1.4] (see Corollary 3.4). This verifies the correctness of the port-Hamiltonian formulation from Proposition 3.2.

Proposition 3.2 contains specific calculation rules for the matrices, functions, and vectors in (5). Hence, the determination of such a PHS can be fully automated in a technical computing systems which makes this approach appealing for the modeling of large-scale systems.

Note that Assumption 3.1 is a restriction as it excludes systems with interdependent energy-dissipating elements. On the other hand, this assumption is justified: in the nonlinear case, the presence of interdependent dissipative elements in general disallows to formulate the system in form of an ODE.

V. Conclusion

In this paper, we presented an explicit port-Hamiltonian formulation of systems with nonlinear dissipation and feedthrough (i.e., Proposition 3.2). We provide calculation rules which enable to compute such a PHS in an automated manner based on the constitutive relations of the energy-storing and energy-disspating elements and the Dirac structure of the system. The PHS is proven to be passive (i.e., Proposition 3.3) and generalizes the well-known "PHS with nonlinear resistive structure" from [9, Def. 6.1.4] by feedthrough (i.e., Corollary 3.4). Future work will address the application of this class of systems for the modeling of mechatronic systems and gas networks.

References

[1] B. Maschke and A. van der Schaft, "Port-controlled Hamiltonian systems: modelling origins and systemtheoretic properties," *IFAC Proceedings Volumes*, vol. 25, no. 13, 1992.

[2] A. van der Schaft and B. Maschke, "The Hamiltonian formulation of energy conserving physical systems with external ports," *AEU - Archiv für Elektronik und Übertragungstechnik*, vol. 49, no. 5-6, pp. 362–371, 1995.

[3] C. Mehl, V. Mehrmann, and P. Sharma, "Stability radii for linear Hamiltonian systems with dissipation under structure-preserving perturbations," *SIAM Journal on Matrix Analysis and Applications*, vol. 37, no. 4, 2016.

[4] P. Kotyczka and L. Lefèvre, "Discrete-time port-Hamiltonian systems based on Gauss-Legendre collocation," *IFAC-PapersOnLine*, vol. 51, no. 3, 2018.

[5] A. van der Schaft and B. Maschke, "Hamiltonian formulation of distributed-parameter systems with boundary energy flow," *Journal of Geometry and Physics*, vol. 42, no. 1-2, pp. 166–194, 2002.

[6] H. Ramirez, H. Zwart, and Y. Le Gorrec, "Stabilization of infinite dimensional port-Hamiltonian systems by nonlinear dynamic boundary control," *Automatica*, vol. 85, pp. 61–69, 2017.

[7] V. Duindam, A. Macchelli, S. Stramigioli, and H. Bruyninckx, Eds., *Modeling and control of complex physical systems: the port-Hamiltonian approach.* Berlin Heidelberg: Springer, 2009.

[8] R. Ortega, A. van der Schaft, F. Castanos, and A. Astolfi, "Control by interconnection and standard passivity-based control of port-Hamiltonian systems," *IEEE Transactions on Automatic Control*, vol. 53, no. 11, 2008.

[9] A. van der Schaft, *L2-gain and passivity techniques in nonlinear control*, 3rd ed. Cham, Switzerland: Springer, 2017.

[10] M. Pfeifer, S. Krebs, F. Hofmann, M. Kupper, and S. Hohmann, "Interval input-state-output estimation for linear port-Hamiltonian systems with application to power distribution systems," in *58th IEEE Conference on Decision and Control (CDC)*, 2019.

[11] A. van der Schaft and D. Jeltsema, "Port-Hamiltonian systems theory: an introductory overview," *Foundations and Trends® in Systems and Control*, vol. 1, no. 2-3, pp. 173–378, 2014.

[12] W. Borutzky, *Bond graph methodology: development and analysis of multidisciplinary dynamic system models.* London: Springer, 2010.

[13] M. Pfeifer, S. Caspart, S. Hampel, C. Muller, S. Krebs, and S. Hohmann, "Explicit port-Hamiltonian formulation of multibond graphs for an automated model generation," *Automatica*, vol. 120, p. 109121, 2020.

[14] M. Pfeifer, S. Caspart, C. Muller, S. Pfeiffer, S. Krebs, and S. Hohmann, "Explicit port-Hamiltonian formulation of bond graphs with dependent storages," in *Proceedings of the 21st IFAC World Congress*, 2020.

Preconditions for Ergonomic Working Places ´2021

Voraussetzungen für den ergonomischen Arbeitsplatz ´2021

Svetla Ivanova-Vassileva

Industrial Design, Technical University of Sofia
Sofia, Bulgaria, vassileva@fdiba.tu-sofia.bg

Abstract — This paper describes the typical preconditions for the ergonomic working place based on the load-stress-concept, paying special attention to physical and psychological aspects. Specific recommendations like modularity, transformability and multifunctionality are introduced as obligatory requirements of great number of online workplaces. The importance of user and functional analyses is emphasized to obtain quality of the working space. Current trends for ergonomic working environment design are presented. An example for ergonomic design of a student dormitory room based on bachelor assignments is given.

Zusammenfassung — Dieser Artikel beschreibt die typischen Voraussetzungen für den ergonomischen Arbeitsplatz nach dem Belastungs-Beanspruchungs-Konzept, indem besondere Aufmerksamkeit auf die physischen und psychischen Aspekte gerichtet wird. Spezifische Empfehlungen wie Modularität, Transformierbarkeit und Multifunktionalität werden als Pflichtanforderungen an eine große Anzahl der Arbeitsplätze für Online-Arbeit vorgestellt. Ein Hinweis auf die Bedeutung von Benutzer- und Funktionsanalyse wird hingewiesen, um eine gute Qualität des Arbeitsumfelds zu erreichen. Es werden aktuelle Tendenzen zur Gestaltung vom ergonomischen Arbeitsumgebung vorgestellt. Es wird ein Beispiel für die ergonomische Gestaltung eines Studentenwohnheimraums anhand von Bachelorarbeiten gegeben.

I. Einführung

Am Anfang der Korona-Pandemie hatte die Telearbeit einschl. der Arbeit im Homeoffice sowie des Online-Lernens und Studierens einen wesentlich niedrigeren Anteil an den menschlichen Tätigkeiten. Dann wurde die extreme Zunahme der Online-Tätigkeiten im Jahr 2020 als eine vorübergehende, zeitlich begrenzte Maßnahme in der Arbeitsorganisation betrachtet. Inzwischen hat sich diese Arbeits- und Bildungsform als ein stabiler Trend erwiesen und ein relevanter Bestandteil unseres Lebens. Infolge dieser Tendenzen sind neben den klassischen ergonomischen Anforderungen an Raum, Lage und Anordnung, Arbeitsmöbel, Arbeitsmittel wie Computer, Arbeitssystem, die von den deutschen Wissenschaftlern und Organisationen gründlich und systematisch analysiert werden [1,2,3], sowie die Berücksichtigung des Belastung-Beanspruchung-Konzeptes [1,4] für eine erfolgreiche Arbeitsplatzgestaltung ´2021 zu betrachten, aber auch die Behandlung dieses Arbeitsplatzes als Teil des Lebensumfelds des Arbeitnehmers, die Notwendigkeit, den vom jeweiligen Wohn- bzw. Arbeitsraum abzugrenzen und oder zu integrieren sowie gegebenenfalls mit anderen Nutzern dieses Raumes oder Teilen davon zu teilen. Dieses Gebiet hat zunehmende Relevanz in den arbeitswissenschaftlichen Forschungen. Und in der dynamischen Entwicklung der Welt muß sich diese Forschung an die Trends anpassen und ständig auf einen unerwarteten Wandel bereit sein.

II. Belastungs-Beanspruchungs-Konzept

Das Belastungs-Beanspruchungs-Konzept gehört zu den erfolgreichen arbeitswissenschaftlichen Vorgehensweisen bei der Anpassung der Tätigkeiten an die inter- und intraindividuellen Eigenschaften der Menschen, d.h. die Menschen unterscheiden sich untereinander, aber Faktoren wie Tagesrhythmus, Konstitution usw. spielen auch zentrale Rolle. Dieses Konzept lautet: die Summe aller Belastungen, die auf den Menschen einwirken, die sich aus der Arbeit, Arbeitsorganisation, Arbeitsmittel und den Umgebungsfaktoren ergeben, verursachen die Beanspruchungen, die mit den individuellen Unterschieden – persönlichen Eigenschaften, Fähigkeiten und Fertigkeiten – zusammenhängen (Abb. 1). Die Belastungen sind nicht nur von der Art, aber auch von der Höhe und Dauer abhängig [1,4,5,6]. Im klassischen Sinne können bei den mehren Homeoffice-Arbeitsplätzen inkl. dieser in den studentischen Wohnheimen folgende relevante Beanspruchungen in zwei Gruppen systematisiert werden: physische und psychische.

A. Traditionelle physische und psychische Beanspruchungen

Bei der Büroarbeit und beim Online-Lernen werden wie bei den traditionellen Computer-Arbeitsplätzen, beschrieben von Arbeitswissenschaftlern, vor allem Skelett, Muskeln, Sinnesorgane (vorwiegend Sehen), Zentralnervensystem beansprucht [7,8]. Einfluss haben der vorhandene Raum, die Finanzmittel der Firma bzw. der Universität für ergonomische Möbel- und Raumgestaltung. Wesentlicher Faktor ist auch der Informierungsgrad aller Beteiligten. Sowie bei den physischen, könnte es auch bei den psychischen Beanspruchungen positive und negative Folgen geben, die zusätzlich in kurzfristigen und langfristigen Beanspruchungen geteilt werden können. Beispiele sind die Aktivierung, Wohlbefinden, Motivation u.a. bzw. Monotonie, Stress, Unzufriedenheit etc. [9].
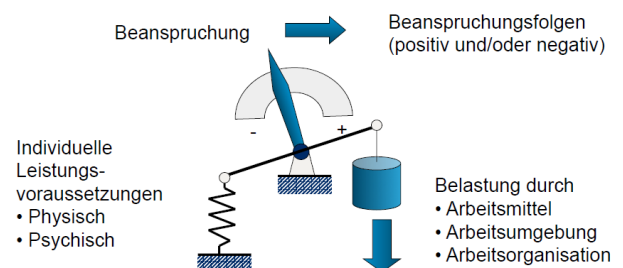

Abb. 1. Belastungs-Beanspruchungs-Konzept nach Rohmert 1984 [7]

B. Trends bei den Belastungs-Beanspruchungs-Faktoren

Manche Belastungs-Beanspruchungs-Faktoren nehmen an Bedeutung zu, z. B. infolge der spezifischen Familien- bzw. Privatleben-Umstände und der rechtlich vorgeschriebenen und personenbezogenen sozialen Distanz, deren Einfluß in den vergangenen zwei Jahren gestiegen ist. Die relevanten Unterschiede, die sich auf die psychische Beanspruchung auswirken, sind individuelle physische und psycho-emotionelle Eigenschaften, wie Motivation, Geschlecht, Alter, Familienumstände, Emotionen, Vorgehensweise etc. Hier ist das Spektrum sehr breit und die Variationen sehr viel.

Die Gestaltung aufgrund des Belastungs-Beanspruchungs-Konzeptes ist eine der Voraussetzungen für einen ergonomischen Arbeitsplatz, da die Berücksichtigung der Auswirkungen physischer und psychischer Belastungen entsprechend der Unterschiede zwischen den einzelnen Benutzern zu weniger negativen Auswirkungen auf die jeweiligen Benutzer führt.

III. Relevanz von Benutzer- und Funktionsanalyse

Um die von der einzelnen Person subjektiv empfundenen Belastungen, die in psychische Beanspruchungen resultieren, zu erforschen, ist die Benutzeranalyse ein passendes Instrument. So kann man die Bedürfnisse und Neigungen, Erwartungen und Bevorzugnisse entdecken, was auch die Basis des UX-Designs zugrunde liegt.

Relevante Einflußfaktoren für die ergonomische Gestaltung sind die Umgebung, die Tätigkeit, die Organisation. Die Funktionsanalyse spielt eine wichtige Rolle für die systematische Untersuchung der Benutzertätigkeiten und deren typischen Reihenfolgen. So werden die Möglichkeiten zur Umstrukturierung der einzelnen Zonen erforscht, sowie die harmonische Verteilung des Raumes zwischen den unterschiedlichen Mitbewohnern entdeckt.

In Tabelle 1 ist ein Beispiel für systematische Liste der verschiedenen Flächen und Räumen dargestellt, die für die Erfüllung der studentischen Aufgaben (Abb. 2, 3, 4 und 6) verteilt wurde. Es wird Fläche vorgesehen, wo einzelnen Möbelstücke oder Arbeitsmittel stehen – *1*, Raum für die Möbelbestandteile, die sich bewegen (z.B. Schubladen, Türen usw. - *2*). Die Fläche von Raumteilen, verbunden mit den Umgebungsfaktoren – *3*, ist auch wichtig. Die Person braucht weiter Platz zum Stehen, Beobachten und Bedienung – *4*. Die Zonen, die zum unterschiedlichen Zweck dienen *(5)*, und die Reihenfolgen von typischen Tätigkeiten *(6)* können mit Farbe oder Strich veranschaulicht werden. Es ist auch wesentlich die Möglichkeiten für Flächentransformation *(7)* darzustellen. Es wird auch der notwendige Freiraum *(8)* vorgesehen.

TABELLE I. FUNKTIONSFLÄCHENVERTEILUNG

|	Funktionelle Skizzen - Bezeichnungen der Zonen
1	Standflächen
2	Funktionsflächen für Maschinen, Ausrichtung, Möbel usw.
3	Fenster, Lichtquellen, Heizkörper, Klimaanlagen usw.
4	Bedienflächen (Standflächen für die Person vor den Möbeln, Einrichtungen, Fensteren usw.)
5	Arbeitsflächen, Lebensraum, Erholungsraum (Farben-, Strich- und Kodierung anderer Art)
6	Lauf- und Bewegungswege Farbenkodierung, Darstellung typischer Funktionsfolgen (-ketten)
7	Transformierungs- und Umstrukturierungflächen und -räume (Darstellung der Überlappung)
8	Freiraum zum Durchgehen
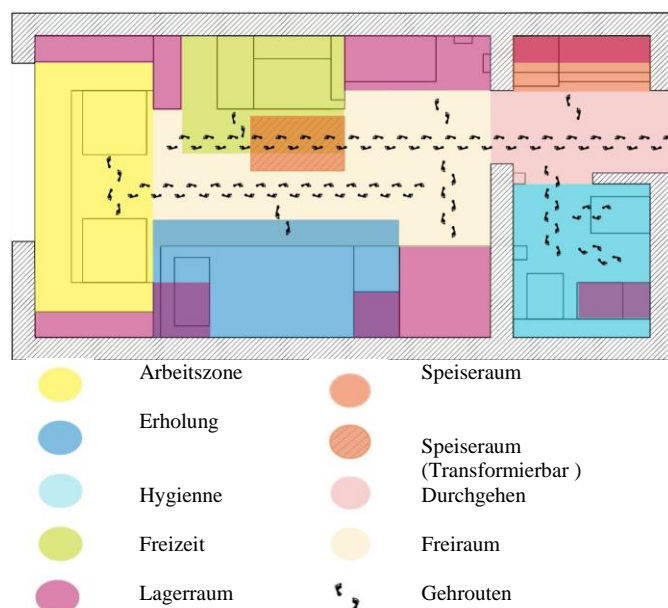
Abb. 2. Funktionsflächen im Studentenwohnheim von TU-Sofia, Aufgabenlösung von Studenten in Fachrichtung Ingenieurdesign, Studienjahr 2020-2021.

Nach der Benutzer- und Funktionsanalyse ist vorteilhaft, Skizzen der funktionellen Zonen (inkl. des Freiraumes) im Raum (Abb. 2) für Arbeiten, Hygiene, Essen, Erholen, Haushalttätigkeiten, Lagern, Durchgehen etc. vorzubereiten Ein relevanter Bestandteil der Arbeitsplatzgestaltung ist die Umgebungsfaktorenanalyse. Es werden die wichtigsten Umgebungsfaktoren anhand verschiedener Darstellungen der Beleuchtung (Tages- und künstliches Licht), Lärm (Quellen und Behebung), Lüftung (Luftzüge, Geruch- und Schimmelbehebung, Vorrichtungen, einschl. Isolierung) (Abb. 3) analysiert, optimiert und geplant.

IV. Trends zur Gestaltung ergonomischer Arbeitsumgebung

Aufgrund der neueren Trends zur Gestaltung ergonomischer Arbeitsumgebung und Empfehlungen von Fachleuten und Unternehmen für das Homeoffice [10, 11] sind neue Vorgehensweisen wie der UX-Design- und der spekulative Design-Ansatz [12] einzusetzen. Dabei sind folgende relevante Komponente benutzerspezifisch zu betrachten: Raum, Fläche und Umgebung, Tisch, Sitz, Monitor und Eingabemittel.

A. Raum und Umgebung

In Bezug auf den Raum lassen sich drei Hauptvarianten zusammenfassen:

- Ein separater Raum für Büro oder ähnliche geistige oder kreative Arbeit (z. B. Büro, Atelier usw.)
- Freistehendes Zimmer für andere Zwecke (z. B. Mansarde, Keller, Wohnzimmer, etc.)
- Teil eines anderen Zimmers (vorwiegend Wohnzimmer). Das ist auch der Fall in einem Studentenwohnheim in Bulgarien (Abb. 4 und 6).

Wichtig für den Erfolg der Gestaltung sind die Untersuchung der Funktionsbereiche bezüglich der Größe und Lage, die Analyse der typischen Tätigkeitsreihenfolgen, die Optimierung der Umgebungseinflüsse wie Beleuchtung, Lärm und Luftqualität besonders bei Multizweckräumen.
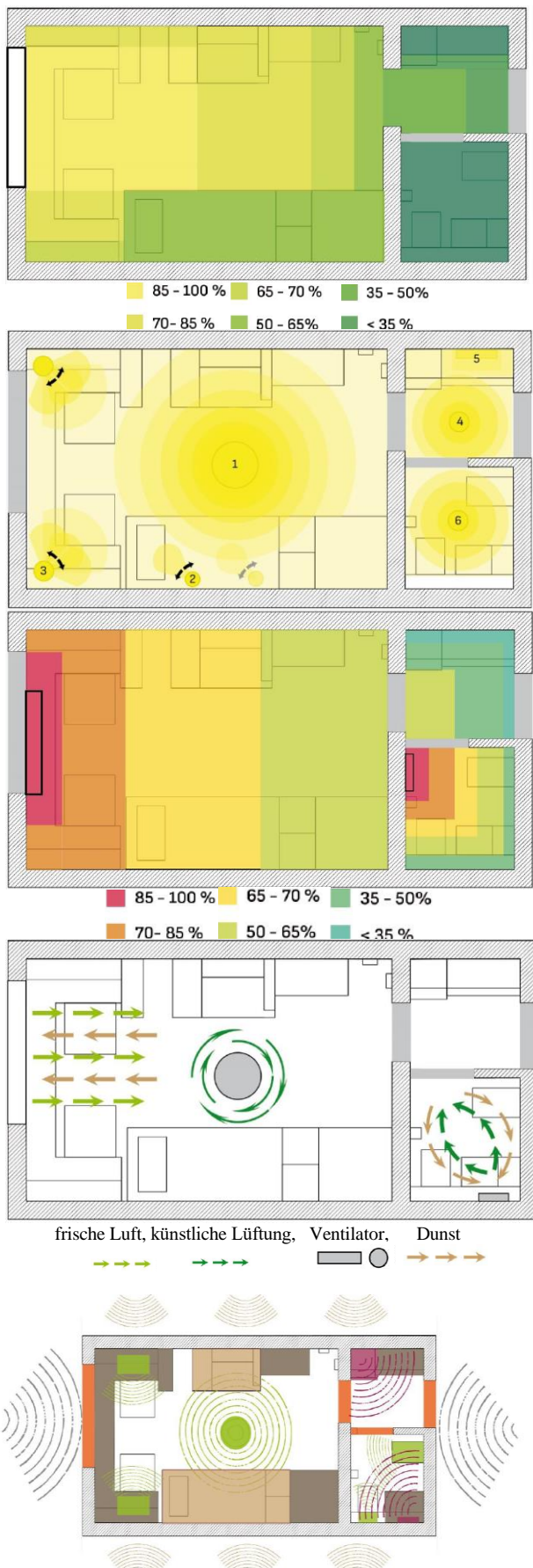
Abb. 4. Beispiele 3D-Visualisierung von Studenträumen, Entwurf für einen Studentenwohnheim von TU-Sofia, Aufgabenlösung von Bachelor-Studenten in Fachrichtung Ingenieurdesign, Studienjahr 2020-2021.

Bei der Analyse und Gestaltung ergonomischer Arbeitsplätze in menschengerechtem und motivierendem Milieu, die immer im Fokus der wissenschaftlichen Untersuchungen bleiben, sind außer der Umgebungs- und Raumplanung auch die Möbelstücke und die Arbeitsmittel im Vordergrund [12,13], da die Ergonomen die gesunde Körperhaltung, ausreichend physische Aktivitäten, verbesserte Leistung, positive Emotionen anstreben, d.h. auch vorwiegend positive Beanspruchungen als Endergebnis.

B. Arbeitsmöbel und Arbeitsmittel

Die wichtigsten ergonomischen Empfehlungen bei Online-Arbeit, die die gute Arbeitsposition einschl. der Abwechslungsmöglichkeit unterstützen, betreffen den Arbeitstisch und den Sitz. Gesundheitsfördernde Lösungen sind nicht nur der traditionelle Computertisch und -stuhl, die das dynamische Sitzen unterstützen, aber auch der elektrisch verstellbare Tisch für Abwechslung der Steh- und Sitzposition von Benutzern verschiedener Körpergröße (Abb. 5). Bei den aktuellen Arbeits- und Lebensbedingungen der Büroarbeit werden eingebaute Sportfunktionen in den Tischen empfohlen, um die gesundheitliche Bewegung im Alltag zu ermöglichen (Abb. 5: Hamster Wheel Standing Desk). Weitere gute Lösungen sind die Fitnessbälle als Sitz. Es gibt auch Dissertationsuntersuchungen über die Geschlechtsunterschiede bei den Sitzanforderungen [14].

Arbeitsraum und -umgebung, -möbel und mittel sind heutzutage auch von der ökologischen Perspektive zu betrachten.

V. EMPFEHLUNGEN ODER OBLIGATORISCHE ANFORDERUNGEN

Neben Komponenten wie der Raum und die Arbeitsmöbel erfordern relevante für die Ergonomie Faktoren wie Modularität, Wandlungsfähigkeit, Multifunktionalität besondere Aufmerksamkeit, indem sie für eine Vielzahl von Online-Jobs zu Pflichtanforderungen werden müssen. In Bezug zu der ergonomischen Gestaltung ist diese Empfehlung in Tabelle 2 vorgestellt.

TABELLE II.   ERGONOMISCHE ANFORDERUNGEN TRANSFORMIERBARKEIT-MODULARITÄT-MULTIFUNKTIONALITÄT

Transformierbarkeit			Modularität
Raum	Fläche	Möbel	
Multifunktionalität			

A. Multifunktionalität

Bei geringem Raum ist die Multifunktionalität der Fläche, der Möbelstücke und Arbeitsmittel die Lösung der Gestaltungsaufgabe (Abb. 6).

Abb. 3. Skizzen - Tageslicht, künstliche Lichtquellen, Wärmeverteilung, Luftbewegung, Lärm in einem Studentenwohnheim von TU-Sofia, Aufgabenlösung von Studenten in Fachrichtung Ingenieurdesign, Studienjahr 2020-2021.
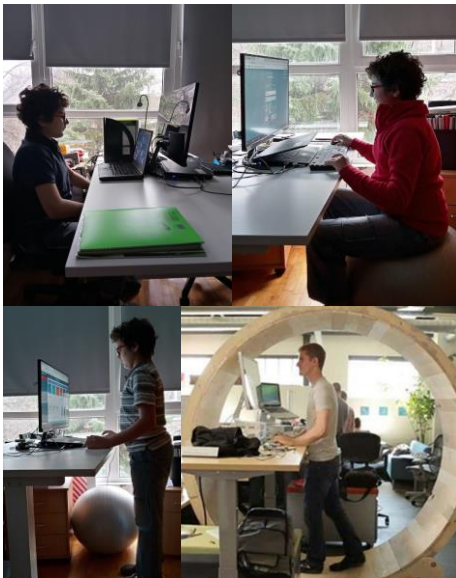
Abb. 5. Home-Office Arbeitsplatz, Hamster wheel standing desk

B. Modularität

Das Modulprinzip ist eine wirtschaftliche und individualisierbare Lösung. In einem Studentenwohnheim ist das eine praktische Vorgehensweise für die Aufgabenlösung aufgrund der verschiedenen Räume und Wohnungen (Einzelzimmer, Familienwohnungen, Behindertenzimmer etc.) in unterschiedlichen Gebäuden (Abb. 6).

C. Transformierbarkeit

Nicht nur bei der Multifunktionalität könnte der geringe Raum auch für die Transformierbarkeit der Möbelstücke und Arbeitsmittel ein Argument sein. Weiterhinaus ist die Tranformation der funktionellen Zonen bzw. die Änderung der räumlichen Verteilung eine Lösung der Optimierungsaufgabe. Auf diese Weise kann man bessere Designalternativen nach den individuellen Benutzerbedürfnissen und Neigungen bieten.

Abb. 6. Beispiel 3D-Visualisierung von Arbeitstisch und Bett für ein Studentenzimmer an der TU-Sofia, Entwurf, Aufgabenlösung von Bachelor-Studenten in Fachrichtung Ingenieurdesign, Studienjahr 2020-2021.

Die Empfehlungen für multifunktionale, transformierbare und auf Modulprinzip gestaltete Arbeitsfläche, -möbel und -mittel in Regeln und Pflichteigenschaften zu wandeln ist nicht nur infolge der begrenzen Räumlichkeiten im Homeoffice und bei Online-Bildungstätigkeiten, aber auch wegen ökologischen Gestaltungsprinzipien.

VI. Zusammenfassung und Ausblick

Die Benutzer- und Funktionanalyse und die Berücksichtigung des Belastungs-Beanspruchungs-Konzeptes können zur besseren Qualität in der Gestaltung ergonomischer Arbeitsplätze in ergonomischer Umgebung führen. Die Modularität, Multifunktionalität, Transformierbarkeit, Umweltfreundlichkeit stehen im Mittelpunkt auch auf dem Gebiet der Ergonomie. Ein Algorythmus zur ergonomischen Gestaltung von Home-Office-Arbeitsplätzen ist empfehlenswert und ein Vorhaben in zukünftigen Forschungen. Die Selbstbewertung mit einem Fragebogen und daraus resultierenden Gestaltungsempfehlungen könnten ein Vorteil bringen. Aufgrund der vorhandenen Varianten [15] kann eine erweiterte Checkliste bezüglich der Arbeitsplätze für Online-Tätigkeiten erstellt werden.

References

[1] Schlick, Ch.M., Bruder, R., Luczak, H., 2010, Arbeitswissenschaft, Springer

[2] REFA, 1991, Methodenlehre der Betriebsorganisation. Grundlagen der Arbeitsgestaltung, Carl Hanser Verlag GmbH, München

[3] Kubitscheck, St., Kirchner JH, 2005, Kleines Handbuch der praktischen Arbeitsgestaltung: Grundsätzliches - Gestaltungshinweise - Gesetze, Vorschriften und Regelwerke - Weiterführende Literatur, Carl Hanser Verlag GmbH & Co., München, Wien

[4] Kirchner JH. 1986, Belastungen und Beanspruchungen — Einige begriffliche Klärungen zum Belastungs- Beanspruchungs-Konzept. In: Hackstein R., Heeg FJ., von Below F. (eds) Arbeitsorganisation und Neue Technologien. Springer, Berlin, Heidelberg

[5] Laurig, W., 1990, Grundzüge der Ergonomie, Beuth Verlag GmbH, Berlin, Köln

[6] DIN EN ISO 26800, Belastungs-Beanspruchungs-Konzept

[7] Stowasser S., 2014, Vorlesungen in Arbeitswissenschaft, Sofia

[8] Luczak, H., Wolf, M., Mühlfelder, M. 2001, Arbeitswissenschaft in CSCW -Kompendium, Lehr- und Handbuch zum computerunterstützten kooperativen Arbeiten, Springer

[9] Baua, 2010, Psychische Belastung und Beanspruchung im Berufsleben: Erkennen – Gestalten, ISBN 978-3-88261-539-5, https://www.baua.de/DE/Angebote/Publikationen/Praxis/A45.pdf?__blob=publicationFile (September 2021)

[10] Landes, M., Steiner, E., Wittmann, R., Utz, T. 2020, Führung von Mitarbeitenden im Home Office. Umgang mit dem Heimarbeitsplatz aus psychologischer und ökonomischer Perspektive, Springer-Gabler Verlag

[11] Oracle und Workplace Intelligence, LLC, Besorgt, verunsichert, gestresst – haben, Mitarbeiter einen kritischen Punkt erreicht? 2020, https://www.oracle.com/a/ocom/docs/applications/hcm/2020-hcm-ai-at-work-study-de.pdf (September 2021)

[12] Ivanova-Vassileva, S., Usability of Speculative Design Products Conference Proceedings of the 15th International Conference "Standardization, Protypes and Quality: A Means of Balkan Countries' collaboration" (October 24 - 25, 2019), Edirne, Turkey, in cooperation with BCC, pp. 261-265

[13] Anguelova, S., New Perspectives On Ergonomics From HF to UX, Avangard Prima, Sofia, 2021, pp. 39-65, ISBN 978-619-239-626-8, (in Bulgarian: Ангелова, С., Нови перспективи в ергономията от човешкия фактор до потребителското изживяване, Авангард Прима, София, 2021, ISBN 978-619-239-626-8)

[14] Nikolova, N., 2021, Untersuchung von Möglichkeiten zur Anwendung wissenschaftlicher Studien, einschließlich bioinspirierter, im Sitzvorrichtungen-Design (in Bulgarian: Изследване на възможности за приложение на научни разработки, включително биоинспирирани, в дизайна на средства за седене), Dissertation, TU-Sofia

[15] DGUV, CHECK-UP Homeoffice - Langversion https://publikationen.dguv.de/forschung/iag/weitere-informationen/4018/check-up-homeoffice-langversion

Doctoral Students

Chair: Marin Marinov

This page is intentionally left blank

A concept to develop and operationalize a ranking of business process model metrics in the context of predictive process monitoring

Florian Spree

Faculty of German Engineering Education and Industrial Management, Technical University of Sofia
Nuremberg, Germany

Abstract — Predictive process monitoring is a subject of a growing interest in academic research and industry. The current status is a poor comparability and comprehensibility due to a high complexity in this research area. To tackle this issue, the paper at hand proposes a concept to establish a benchmark using a ranking of business process model metrics. The aim is to reduce the lack of understanding and further increase the probability of a positive prediction outcome. In order to address the issues, the concept has to identify and categorize business process model metrics, provide a ranking of business process model metrics, introduce an integrated approach in the existing framework and finally propose a solution approach of how the concept can be operationalized.

I. INTRODUCTION

Business process monitoring is a central component in business process management to improve the performance of organizations. Traditional process monitoring methods combined with the availability of process execution data provide managers and analysts with an overview of the current performance and thus establish a way to intervene accordingly. Next to traditional process monitoring techniques - which only provide a snapshot of the current performance - a growing interest in the prediction of process outcomes has led to the emergence of predictive process monitoring (PPM) [8], [14], [17]. In recent years, organizations and researchers exploit prediction models in order to improve process performance and mitigate risks [11]. There are many scenarios where it is useful to have reliable process predictions, such as predicting compliance violations [3], the remaining sequence of activities [5], [12], or the remaining execution time of a case [4], [10]. Due to the high complexity in this research area, a wide range of different experimental setups and methods exists. Meaning that researchers have used different prediction models, data sets, domains or prediction goals.

The objective of this paper is to improve the comparability and comprehensibility of experimental setups by proposing a concept to establish a ranking for business process models characteristics in the context of PPM and further make the ranking accessible in an intuitive and easy way. The motivation hereby is to establish a benchmark using business process models metrics in future work.

The remainder of the paper is organized as follows: The second section describes the framework of PPM and what role business process models play. Section three points out the research problem, followed by the research methodology in section four. In section five the concept gets introduced in detail which identified four academic contributions in order to develop and operationalize a ranking of business process model metrics in the context of PPM. Finally, the last section summarizes the academic contribution of this paper and discusses future work.

II. RESEARCH AREA

The PPM methodology aims to predict the future of quantifiable values during a running process execution [6], [11]. The core of every experimental PPM setup is to build an accurate prediction technique. In the research field of PPM, the frameworks proposed by [7], [8] are commonly used when performing experiments. In general, the methodology can be divided into two steps: training and runtime as visualized in figure 1.
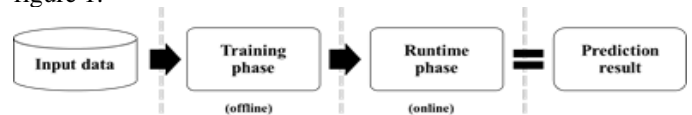

Fig. 1 Experimental setup for predictive process monitoring

In the training phase, the prediction model is built from finished (offline) input data. The technical format of input data consists either of event streams or event logs. Regardless of the technical format, the main input data for PPM methods are finished traces, which further can be classified according to [5] in four different perspectives: the control-flow perspective (concerns the order and relation of activities), the data-flow perspective (concerns the data attributes attached to events), the time perspective (concerns various types of duration such as service times, flow times, waiting times) and the resource/organization perspective (concerns the resource executing the event or corresponding activity). Depending on the used prediction model it is not necessary to provide all input data perspectives for training. For example, [7] differentiates between process-aware and non-process aware prediction models. Approaches that are process-aware consider the control-flow perspective as input data explicitly whereas methods that are non-process aware consider the control-flow perspective implicitly. In this paper, only approaches that are process-aware will benefit from the ranking of business process model characteristics. However, after identifying the input data it is necessary to describe an encoding to prepare the relevant information to finally use the manipulated data to train the prediction model. Further, the type of prediction model specifies the type of prediction outcome assessment: in case of classification methods, classification measures such as

precision are used. In case of regression methods, regression measures such as root-mean squared error are commonly used. In the second phase, the trained prediction model exploits data corresponding to running and unfinished (online) traces to predict the outcome during runtime [6]. Based on the prediction result, the idea is to enable the business to proactively improve process performance and mitigate risks [10].

III. RESEARCH PROBLEM

As shown in section two, business process models can play a crucial role in the area of PPM. To consolidate the need of business process models in the context of PPM a broad literature review of experimental setups was conducted in [13]. As a result, the field of use and the associated research gaps are identified. One key gap is the lack of understanding how and to what extent the technical structure of business process models affects the prediction outcome. There is currently no consensus on how to use business process model metrics as a benchmark to ensure comparability and understandability although different authors have already used different metrics for business process models in different constellations. These observations strengthen the need of a concept to develop and operationalize a ranking of business process model metrics and establish a generic benchmark. To do so, the concept addresses the following research questions in this paper:

1. ***Research question (RQ1):*** How to identify and categorize relevant business process model metrics?
2. ***Research question (RQ2):*** How to rank business process model metrics in the context of prediction outcome?
3. ***Research question (RQ3):*** How to embed the ranking of business process models in the framework of predictive process monitoring?
4. ***Research question (RQ4):*** How to operationalize metrics as an incremental software approach?

Consequently, the concept aims to quantify what, how and to what extent business process models can affect prediction outcomes and how the concept can be publicly available. In other words, the goal of the project is to move the state of the art in the use of business process model metrics as a benchmark from ad-hoc approaches to a universal solution to support researchers and practitioners in the context of PPM.

Beside the presented research questions, the analysis of the area of research reveals an early stage of development and is accordingly connected to many challenges. In order to meet these challenges, limitations are formulated. The first limitation stems from the fact that due to a high complexity a wide range of different experimental setups and methods exists. This results in a huge possible combination of different prediction models, amount of available data, quality of data, manipulation of data and types of prediction outcome. By following the goal to generate a ranking based on business process model metrics, the information is provided but excluded in drawing scientific conclusions despite having the awareness those factors play an important role. Moreover, explaining the reason for the degree of impact of each metric is strictly limited to the observation during the experiment and the formulation of possible hypotheses. Finally, despite the limitations considering resources such as time, a degree of generalizability is given which then can be used as a springboard to suggest future research.

IV. RESEARCH METHODOLOGY

In line with the research problem, the solution approach will be verified by using, on the one hand, a qualitative strategy and, on the other hand, the design science method by creating a software artefact. The qualitative strategy can be divided into two steps. First, a set of business process model metrics gets identified by conducting a literature review. Secondly, an experimental setup is introduced to rank the metrics based on their impact in the context of prediction outcome. Finally, the results will be devised and operationalized in a software prototype that follows the design science research method, since the listed contributions cover design aspects [7].

V. SOLUTION APPROACH

To address the research questions, the paper proposes a solution approach for each research question. In the first step of the concept, business process model metrics are identified and categorized in a standardized way. Further, an experimental concept to rank business process metrics based on their impact on prediction outcome is proposed. Afterwards a solution approach to embed the ranking into the existing PPM framework gets proposed. Lastly, to make the ranked metrics publicly available, the idea of the concept is to consolidate the academic contributions into a web-based business process model metric suite. In summary, the ranking of business process model metrics will be quantified and then operationalized in a web-based metric suite that allows researchers and practitioners to receive assistance in a generic manner. In the following, a detailed description is proposed on how to answer the identified research questions.

A. RQ1 - How to identify and categorize relevant business process model metrics

The need for comparability and comparison in regard of business process models in the context of PPM has been pointed out in [13]. The results further underline the scientific need to develop a ranking of business process model metrics. To propose a ranking, the first step is to identify and categorize business process model metrics. Business process model metrics have to fulfill the following criteria in order to be perceived as relevant:

- *Calculability* - The execution of the metric should lead in finite time to a result
- *Implementation* - The metric should be implementable with reasonable effort
- *Repeatability* - Metric measurement results must be repeatable regardless of the person performing or the executed software tool
- *Automation* - The metric must be executable in an automated way
- *Comprehensibility* - The metric is easy to understand

After conducting a literature review, including 48 papers, and applying the mentioned criteria, 16 metrics are identified and assigned to five categories. The result of answering RQ1 is shown in the following table.

CATEGORY	METRICS
Size	Number of activities (NOA), Number of activities and control-flow elements (NOAC), Coefficient of Network Complexity (CNC), Density
Structure	Separability, Sequentiality. Diameter
Operators	Maximum nesting depth, Average degree of connectors, Maximum degree of connectors, Binary decisions, Control flow complexity (CFC), Concurrency
Cycle	Cyclicity, Cyclomatic Number
Cognitive weight	Cognitive weight

The first category *Size* includes all metrics that concern the physical size of how big a business process model is. A classic example is the simple counting of graphical elements in different combinations such as NOA or NOAC. By taking the prediction outcome into account, the hypothesis is that bigger business process models have a greater impact in influencing the prediction outcome. Thus, several papers point out that *Size* is an important factor for the comprehensibility and comparability of software and business process models [1], [2], [6], [15]. Because *Size* alone doesn't matter, the category *Structure* gets introduced as a generic term that refers to any metric that focuses on the arrangement of graphical elements to each other. Consequently, *Structure* measures the depth or sequentiality of a business process model based on single graphical elements. It is hypothesized that business process models with greater depth or a low sequentiality are more difficult to predict because the number of available tracks is assumed to influence the prediction outcome. The third category *Operator* refers as a generic term to all metrics that relate to the relationship between logical operators and their relationship among them. In the context of prediction, the hypothesis is that business process models with a great amount or variety in regard of operators can indicate a negative effect on the prediction outcome. The category *Cycle* presents all metrics of the business process model which focus on repetition of graphical elements. Cycles are presumably more difficult to understand than sequential parts. Consequently, it is assumed that a high occurrence of cycles affects the prediction outcome in a negative way. Finally, the last category *Cognitive weight* examines the process model by graphical elements on how information is understood. It is assumed that a high *Cognitive weight* has a negative impact on the prediction outcome because of an increase in complexity which may is directly connected to the other categories.

B. RQ2 - How to rank business process model metrics in the context of prediction outcome

A promising approach to rank metrics is to evaluate already conducted experimental setups and to compare their available information among each other by using business process model metrics. Figure 1 visualizes the experimental setup of how to rank the identified and categorized business process model metrics in the context of PPM in five steps.
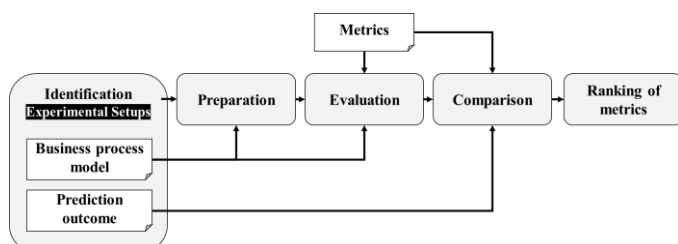

Fig. 2 Experimental approach to rank business process model metrics

In the first step process-aware experimental setups get *identified*. The data then gets searched for two types of information: the applied business process model and the prediction outcome. On the one hand, the business process model as a evaluation basis for metrics and on the other hand, the prediction result as a central success factor in order to be able to compare the experimental setups among each other. It is assumed that one business process model can always be linked to exactly one prediction model and therefore results in exact one prediction outcome. To ensure comparability and an equivalent data basis among all experimental setups it is necessary to provide the same format and graphical elements for each business process model. Because the standard is BPMN 2.0. a *preparation* can be necessary for example by converting process flows into BPMN 2.0 models. After the preparation of business process models is complete, the *evaluation* by metrics can be performed and documented. For the evaluation of business process models the business process model metrics listed in table 1 are used. The evaluation is performed manually and automated to minimize the error probability in the evaluation step. In the second last step the created data of the evaluation gets *compared* among all experimental setups. The hypothesis claims that different types of prediction outcome can be linked to specific values of business process model metrics. The evaluation of the experimental approach takes place with the help of different statistical methods. Here, the metrics are put into context with the prediction results. Based on this observation, it is possible to propose a *ranking* of metrics and quantify their importance in the context of prediction results.

C. RQ3 - How to embed the ranking of business process models in the framework of predictive process monitoring

The paper has identified two promising approaches to make use of business process models in the framework of PPM. First, the metrics can be used to prevent an undesired outcome before the prediction has been progressed based on the research result of the ranking. Secondly, the metrics can be used after the prediction to provide comparability and comprehensibility for other researchers. Both approaches can be linked to specific steps in the framework of PPM as visualized in figure 3.
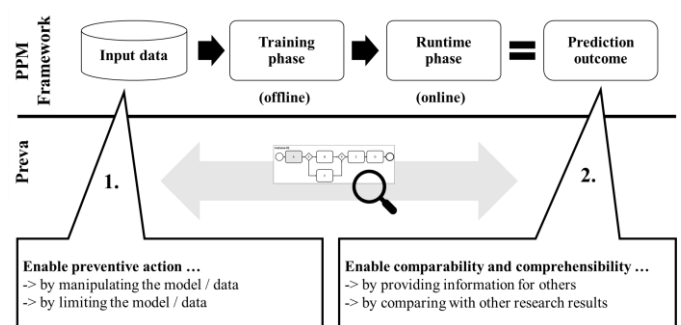

Fig. 3 Embedding business process model metrics in the framework of PPM

In the first approach the main goal is to prevent undesired outcomes based on the ranking of business process model metrics before the prediction outcome. The idea is to enable practitioners and researchers to intervene accordingly based on the result of the ranking before the training phase. Possible countermeasures can be on the one hand, the manipulation of the business process model by removing/adding new graphical elements. On the other hand, to limit the business process model for example by downsizing the relevant process path.

The second approach follows the idea to enable comparability and comprehensibility after the prediction outcome. Preva enables practitioners and researchers to provide business process model metrics as a benchmark in an intuitive and standardized way. The result can for example be exported and attached to research work. This feature ensures a long-term support and quantity way to compare different research results.

D. RQ4 - How to provide metrics as an incremental software approach?

The web-based software approach called "Preva" (an acronym for "process evaluation") consolidates and operationalizes the scientific contributions of RQ1, RQ2 and RQ3. Meaning, to automatically generate a categorized and ranked view of different business process model metrics. Therefore, the software can be identified as a metrics suite. From an architectural point of view the software consists out of four components which can be progressed in a chronological order: Upload, Evaluation, Dashboard and Export (see figure 2).
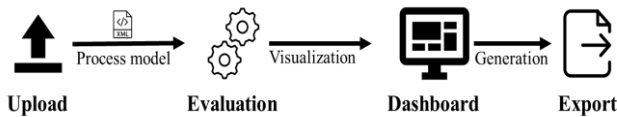
Fig. 4 Software concept to rank business process model metrics

The first step is to *upload* a business process model as a BPMN 2.0 format file. This limitation arises from technical restrictions related to the evaluation of business process models. The uploaded business process model then will be *evaluated* based on business process model metrics. The result gets *visualized* in a dashboard. The user then can filter the values based on the categorization or ranking. The goal is to provide researchers and practitioners an indication of how the business process model may influence the prediction outcome in a positive or negative way. The indication is referenced on the ranking of metrics. Finally, to allow comparability and comprehensibility an *export* is available which can be attached to recent work. In summary, the software concept allows researchers to quantify and document characteristics of business process model as a benchmark in a standardized way.

II. CONCLUSION AND FUTURE WORK

In this section the present academic contribution in line with the formulated research questions is concluded. First to address *RQ1*, business process model metrics got identified and categorized. Specifically, 16 metrics are mapped to five categories. The identification of business process model metrics was conducted by a literature review including 48 papers. The categorization was performed manually, similar approaches exists in [9], [16]. The outcome of RQ1 is visualized in table I. Next, *RQ2* has been tackled by proposing an experimental concept to evaluate business process models based on their impact in the area of PPM. The evaluation to create a ranking of business process model metrics consists out of five steps. The outcome of the concept can be formalized in a next paper. To address *RQ3*, two promising approaches got developed. The first approach enables practitioners and researchers to intervene accordingly based on the result of the ranking before the training phase. The second approach follows

the idea to enable comparability and comprehensibility after the prediction outcome by using business process model metrics as a benchmark. Finally, to address *RQ4* a first prototype of preva has already been developed to proof its technical feasibility. The prototype is currently in the alpha phase and can be viewed publicly at www.processevaluation.de

In conclusion, the paper explained a detailed outline of the concept and associated research questions. Based on the identified research questions solution approaches are proposed to move the state of the art of using business process model metrics as a benchmark from ad-hoc approaches to a universal solution. Future work is to publish the ranking results and further to develop preva until a level of maturity useful to the public.

REFERENCES

[1] Canfora, G., García, F., Piattini, M., Ruiz, F., and Visaggio, C. A.: A family of experiments to validate metrics for software process models., J. Syst. Softw., vol. 77, no. 2, pp. 113–129, (2005).

[2] Cardoso, J., Mendling, J., Neumann, G., and Reijers, H. A.: A Discourse on Complexity of Process Models., in BPM 2006: Business Process Management Workshops, Springer, Berlin, Heidelberg, pp. 117–128, (2006).

[3] Castellanos, M., Casati, F., Dayal, U., and Shan, M.-C.: A Comprehensive and Automated Approach to Intelligent Business Processes Execution Analysis., Distrib. Parallel Databases, vol. 16, no. 3, pp. 239–273, (2004).

[4] van Dongen, B. F., Crooy, R. A., and van der Aalst, W. M. P.: Cycle Time Prediction: When Will This Case Finally Be Finished?., in OTM 2008: On the Move to Meaningful Internet Systems: OTM 2008, pp. 319–336, (2008).

[5] Evermann, J., Rehse, J.-R., and Fettke, P.: A Deep Learning Approach for Predicting Process Behaviour at Runtime., in International Conference on Business Process Management 2016, pp. 327–338, (2017).

[6] Fenton, N. E. et al.: Software Metrics (2nd Ed.): A Rigorous and Practical Approach. 2nd Editio.USA: PWS Publishing Co., (1997).

[7] Hevner, A. R., March, S. T., Jinsoo Park, and Sudha Ram: Design Science in Information Systems Research., MIS Q., vol. 28, no. 1, p. 75, (2004).

[8] Maggi, F. M., Di Francescomarino, C., Dumas, M., and Ghidini, C.: Predictive Monitoring of Business Processes., in Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 8484 LNCS, pp. 457–472, (2014).

[9] Mendling, J.: Metrics for Business Process Models., pp. 103–133, (2008).

[10] Rogge-Solti, A. and Weske, M.: Prediction of Remaining Service Execution Time Using Stochastic Petri Nets with Arbitrary Firing Delays., in ICSOC 2013: Service-Oriented Computing, pp. 389–403, (2013).

[11] Salfner, F., Lenk, M., and Malek, M.: A survey of online failure prediction methods., ACM Comput. Surv., vol. 42, no. 3, pp. 1–42, (2010).

[12] van der Spoel, S., van Keulen, M., and Amrit, C.: Process Prediction in Noisy Data Sets: A Case Study in a Dutch Hospital., Int. Symp. Data-Driven Process Discov. Anal., pp. 60–83, (2013).

[13] Spree, F.: Business Process Models in the Context of Predictive Process Monitoring., Rev. Informática Teórica e Apl., vol. 28, no. 1, pp. 39–46, (2021).

[14] Spree, F.: Predictive Process Monitoring: A Use-Case-Driven Literature Review., EMISA Forum, vol. 40, (2020).

[15] Stephen H. Kan: Metrics and Models in Software Quality Engineering. (2002).

[16] Vanderfeesten, R., Cardoso, J., Mendling, J., Reijers, H. A., and van der Aalst, W. M. P.: Quality Metrics for Business Process Models., Work. Handb., pp. 179–190, (2007).

[17] Verenich, I.: A general framework for predictive business process monitoring. vol. 1603 (2016).

Battery Energy Storage System – Benefits and Risks

Batterie-Energiespeichersystem – Vorteile und Risiken

Nikolay Kambosev

FDIBA, Technical University of Sofia
Sofia, Bulgaria, kambosev@gmail.com

Abstract — This article describes the benefits and risks of the battery energy storage system. It provides information about the battery energy storage system, the main manufactures and solution providers, and its future market trends. It shows examples of the disadvantages related to battery energy storage system, which will be the challenges for all companies and organizations connected with the power industry in the next 10 years.

Zusammenfassung — Dieser Artikel beschreibt die Vorteile und Risiken des Batterie-Energiespeichersystems. Er informiert über das Batterie-Energiespeichersystem, die wichtigsten Hersteller und Lösungsanbieter, und zukünftige Markttrends. Er zeigt die Nachteile von Batterie-Speichersystem, die in den nächsten 10 Jahren die Herausforderungen für alle Unternehmen und Organisationen mit Bezug zur Energiewirtschaft darstellen werden.

I. INTRODUCTION

With the increasing energy needs of households and businesses, the load on the power grid is enormous. Along with reducing carbon emissions, energy and automation industries face major challenges. The short time in which the new systems need to be transformed and implemented leads to both benefits and risks for business and society. Therefore, in the following chapters we will take a look at what a battery energy storage system is, what types of energy storage exist, their benefits and risks?

II. WHAT IS THE BATTERY ENERGY STORAGE SYSTEM AND ITS BENEFITS

Battery energy storage system ensures the balance in the power grid. It allows renewable energy to be stored and supplied when needed and it could be used as stand-alone solutions to help with fluctuating power supply and demand. The battery energy storage system also could be a back-up for the instant power supply.

This optimisation of energy output to the grid means that renewable energy and battery energy storage system provide power at both peak and non-peak times, stabilising the distribution network. This also allows investors and stakeholders to realize increased revenue income resulting from limited wastage while reducing costs for consumers [1]. Figure 1 shows a diagram of peak shifting between the charge during the off-peak times and discharge during the peak times.

Energy storage devices are shown on figure 2 which can be used according to discharge time at rated power and system power ratings. It shows the comparison between the power output and energy consumption. The figure 2 also presents the main technologies for storage capacity.

They can be used for uninterruptible power supply (UPS), transmission and distribution (T&D) system support, or large-scale generation, depending on the technology applied and storage capacity. Among electrochemical, chemical, and physical energy storage devices, the technologies that have received the most attention recently fall within the scope of UPS and T&D system support. Representative technologies include reduction–oxidation (redox) flow, sodium–sulfur (Na–

S), lead–acid and advanced lead–acid, super-capacitor, lithium, and flywheel batteries. Lithium batteries are in common use today [2].
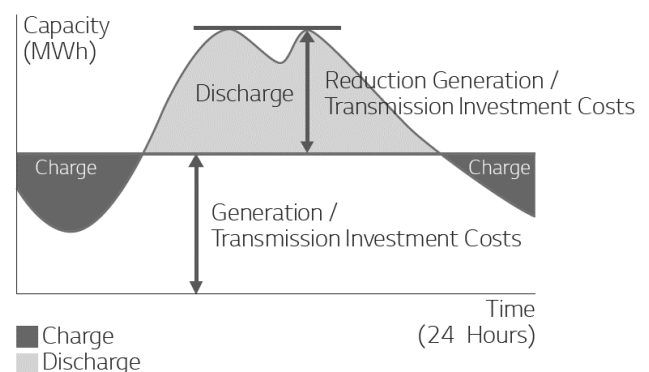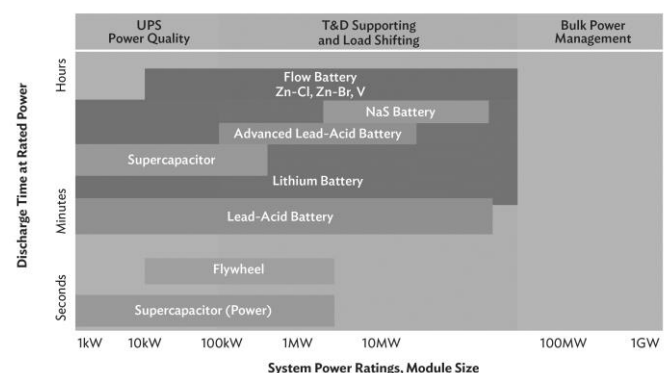

Fig. 1 Peak Shifting [3]

Fig. 2 Comparison of Power Output and Energy Consumption [2]

One of the reason is decreasing price of the Lithium-ion battery pack by 89% from 2010 to 2020, with the volume-weighted average hitting \$137/kWh. Underlying material prices will play a larger role in the future, but the introduction of new chemistries, new manufacturing techniques and simplified pack designs keeps prices falling [4].
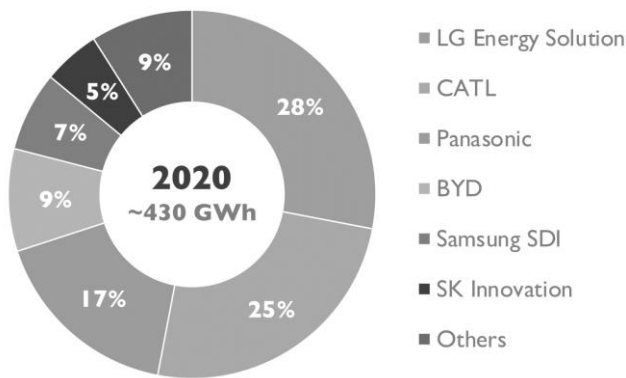
Fig. 3 2020 top battery manufacturers market shares in GWh [5]

Figure 3 shows the split between the main batteries manufactures in 2020. Demand for lithium-ion batteries will increase rapidly in the coming years, hence there will be a big competition between the existing manufactures and the new start up ones. With 28 percent, LG Energy Solution ranks first in the production of lithium ion batteries.
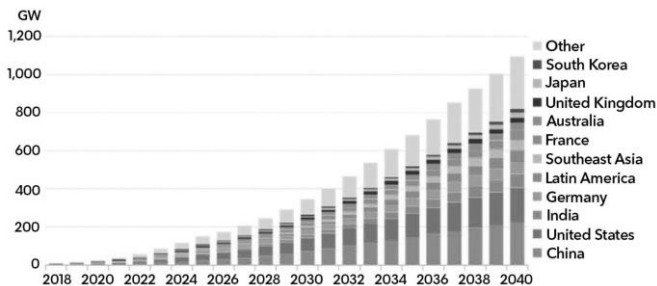

Fig. 4 Global cumulative energy storage installations [6]

Energy storage installations around the world will multiply exponentially, from a modest 9GW/17GWh deployed as of 2018 to 1,095GW/2,850GWh by 2040, according to the latest forecast from research company Bloomberg NEF (BNEF) [6].
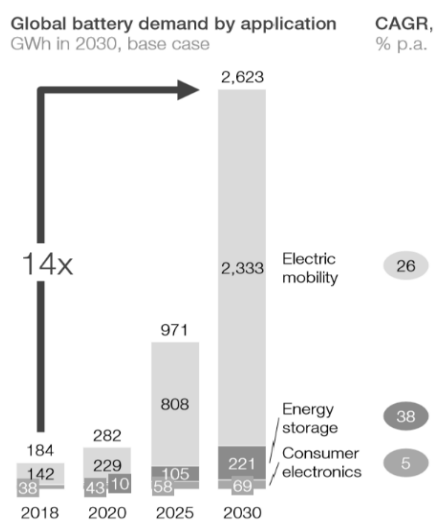
Fig. 5 Global battery demand by application [7]

There is a fundamental transition developing in the power system and transportation sector. Falling wind, solar and battery costs mean wind and solar are set to make up almost 40% of world electricity in 2040, up from 7% today. Meanwhile passenger electric vehicles could become a third of

the global passenger vehicle fleet by 2040, up from less than half a percent today, adding huge scale to the battery manufacturing sector. The demand for storage will increase to balance the higher proportion of variable, renewable generation in the electricity system. Batteries will increasingly be chosen to manage this dynamic supply and demand mix [6].

Figure 4 and 5 show the forecast of the global battery demand by the application and region.
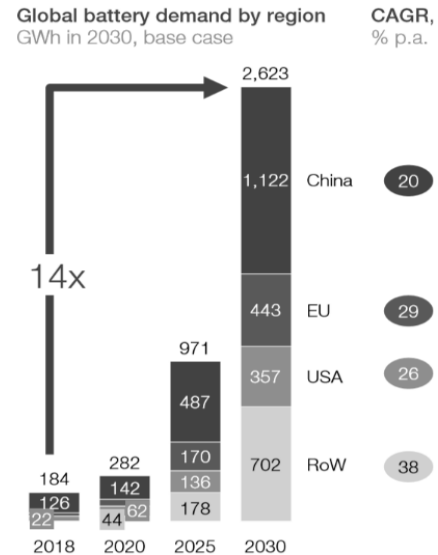

Fig. 6 Global battery demand by region [7]

The companies which offer battery storage system solutions are Mitsubishi Heavy Industries, Tesla, ABB Hitachi, Siemens, Honeywell, LG Energy Solution, Man Energy Solutions, CATL and General Electric. They offer not only battery storage solution but and full automation control and observation.

There are many projects which are fulfilled worldwide:
- 400-MWh Saticoy energy storage project using Tesla Megapacks which is operating now in Southern California;
- The Minami-Soma Substation – 40,000kW energy storage project located in Minamisoma, Fukushima, Japan [8];
- Jinjiang 100 MWh energy storage power station project – China [9].

III. RISKS

Along with the benefits that battery energy storage system brings, it also has accompanying risks. The major risk are fire or explosion, augmentation, and developing of a new battery breakthrough storage.

A. Thermal runaway

By storing of a large amount of energy there is a risk that an uncontrolled release of the energy could result in a fire or explosion. In batteries, thermal runaway describes a chain reaction in which a damaged battery begins to release energy in the form of heat, leading to further damage and a feedback loop that results in rapid heating. Left unchecked, the heat generated can cause a fire. The figure 7 shows an example of thermal runaway feedback loop. The only way to stop thermal runaway is rapid cooling of the affected cell(s); another approach is to simply separate the affected battery module and allow the reaction to reach its destructive conclusion in a safe location [10].
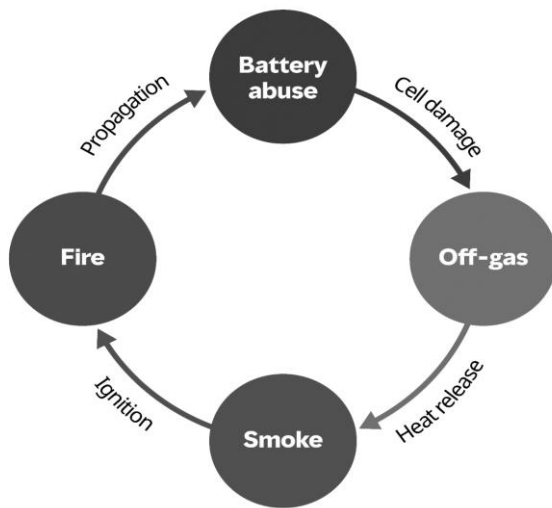
Fig. 7 Thermal runaway feedback loop [10]

According to Marsh global risk management company recent survey found insurers of battery energy storage system facilities were most interested in the fire protection features, followed closely by space separation between battery enclosures. To assess emergency response, underwriters look for evidence of detailed dialogue with emergency services and a written protocol for incidents (documented pre-fire plans). Ultimately, early engagement with the company risk adviser is a key to ensuring that company project is well protected, safe, reliable, and well positioned to benefit from a competitive insurance placement for the long-term life of the project [10].

Global battery energy storage system fire events in Europe and North America have highlighted that failures are not unique to a particular manufacturer or design, but that the hazard is inherent in the technology.

The figure 8 shows a battery storage container on fire in South Korea.

Fig. 8 Battery energy storage system on fire [11]

The report of South Korea which investigates 23 energy storage system fires that have occurred since August of 2017 are announced in 2019 that there four causes for the fires:

1. Insufficient battery protection systems against electric shock
2. Inadequate management of operating environment
3. Faulty Installations
4. ESS System Integration

The report concludes that the lithium-ion battery fires results in system losses valued at over $32M USD. The government requested to stop operation of existing systems which resulted the shutdown of 522 ESS units – approximately 35% of the budding market [11].

B. Augmentation

To offset anticipated degradation of a battery system augmentation is a typical strategy. The augmentation is the process of adding additional capacity at select times to the system to ensure it meets a customer-desire threshold for total capacity. Figure 9 shows two strategies for providing a minimum battery capacity, 9MWh in this example. The first strategy does not include augmentation, but instead provides substantial oversizing of the battery. In the second case, the battery capacity is augmented twice in order to retain the required capacity. As a result, the initial battery size is smaller. As part of the system modelling, the company will provide a recommended approach to ensure the capacity that meets the financial needs of the customer [12].
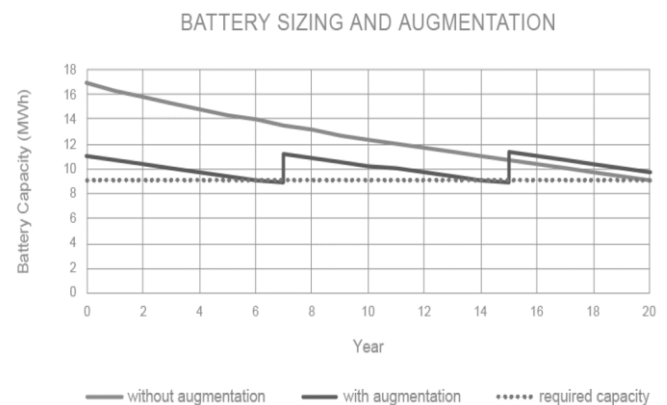

Fig. 9 Battery sizing and augmentation [12]

IV. BATTERY 2030+

BATTERY 2030+ is the large-scale and long-term European research initiative with the vision of inventing the sustainable batteries of the future, providing European industry with disruptive technologies and a competitive edge throughout the battery value chain and enabling Europe to reach the goals of a climate-neutral society envisaged in the European Green Deal [13]. With a total budget of EUR 40,5 million, seven projects will contribute to the implementation of ultrahigh-performance, reliable, safe, sustainable and affordable batteries[14]. The BATTERY 2030+ roadmap will promote a circular economy with reduced waste, small CO_2 footprint, and more intelligent use of strategic resources [7].

The mission is to transform the EU's economy for a sustainable future, to make Europe the first climate-neutral continent by 2050 and to live up to the United Nations' Agenda 2030 and Sustainable Development Goals [7].

The chemistry-neutral approach of the Battery 2030+ consist of:

1. Accelerated discovery of interfaces and materials
   - Batteries Interface Genome
   - Materials Acceleration Platform

2. Integration of smart functionalities
   - Sensing
   - Self-healing

3. Cross-cutting areas
   - Recyclability
   - Manufacturability

Thanks to this chemistry-neutral approach, BATTERY 2030+ will have an impact not only on current lithium-based battery chemistries, but also on post-lithium batteries, including redox flow batteries and on still unknown future battery chemistries [7].

V. CONCLUSION

The lithium batteries are conventional, and until the development of a new technology, the battery storage system will continue using lithium batteries technology for storage and supply to the power grid. Despite of the risks associated with the lithium batteries technology, the benefits for the industries and utilities are the most economically profitable solution which ensures sustainable power supply. Furthermore, this technology will define the future energy market price.

REFERENCES

[1] Jack Wieland, "The rise in Battery Energy Storage Systems," (2021) [Online]. Available at: https://www.marsh.com/uk/industries/energy-and-power/insights/rise-in-battery-energy-storage-systems.html

[2] Asian Development Bank, Handbook on Battery Energy Storage System, Asian Development Bank, 2018, pp.3.

[3] Grid-scale and C&I (2021) [Online]. Available at: https://www.lgessbattery.com/us/grid/intro.lg

[4] Electric Vehicle Outlook 2021 (2021) [Online]. Available at: https://about.bnef.com/electric-vehicle-outlook/

[5] Li-ion battery market on a 23% CAGR (2021) [Online]. Available at: https://www.electronicsweekly.com/news/business/li-ion-battery-market-23-cagr-2021-08/

[6] Energy Storage Investments Boom As Battery Costs Halve in the Next Decade (2019) [Online]. Available at: https://about.bnef.com/blog/energy-storage-investments-boom-battery-costs-halve-next-decade/

[7] INVENTING THE SUSTAINABLE BATTERIES OF THE FUTURE, Research Needs and Future Action (2020) [Online]. Available at: https://battery2030.eu/digitalAssets/860/c_860904-l_1-k_roadmap-27-march.pdf

[8] Minami-Soma Substation – BESS, Japan (2021) [Online]. Available at: https://www.power-technology.com/marketdata/minami-soma-substation-bess-japan/

[9] Jinjiang 100 MWh energy storage power station project (2021) [Online]. Available at: https://www.catl.com/en/othercase/485.html

[10] Chris Taylor, "Battery Energy Storage Systems and the rising risk of thermal runaway" (2021) [Online]. Available at: https://www.marsh.com/uk/industries/energy-and-power/insights/battery-energy-storage-systems-and-rising-risk-of-thermal-runaway.html

[11] Steve Cummings, "South Korea Identifies Top 4 Causes for ESS Fires" (2019) [Online]. Available at: https://liiontamer.com/south-korea-identifies-top-4-causes-that-led-to-ess-fires/

[12] L1000 Distributed Energy Storage System Product Bulletin (2017) (2021) [Online]. Available at: https://www.johnsoncontrols.com/-/media/jci/des/files/26671_jc_l1000productbulletin_mm1-052517.pdf

[13] BATTERY 2030+ (2021) [Online]. Available at: https://battery2030.eu/about-us/

[14] BATTERY 2030+ (2021) [Online]. Available at: https://battery2030.eu/

The right of priority in trademark registration-
Is the Bulgarian legislation comprehensive?

Das Prioritätsrecht bei der Markeneintragung –
ist der bulgarische Rechtsrahmen ausreichend?

Dimitrina Stefanova,

Faculty of German Engineering Education and Industrial Management, Technical University -Sofia
8, Kliment Ohridski Blvd, BG – 1000, Sofia, Republic of Bulgaria, dimitrina.stefanova@gmail.com

Abstract — This report researches the examination of the right of priority within the registration procedure under Bulgarian legislation for trademark protection. The report raises the issue of regulatory gaps, incomplete regulation and fragmentation of these regulations - all issues that may affect the business and its interest in the registration procedure. A comparative analysis is made with the proceedings for registration of a European trademark and the examination of the right of priority according to the European legislation. Based on this comparative analysis, the author made proposals to improve the Bulgarian legislation, such as the Law on Marks and Geographical Indications to comprehensively regulate the examination of the right of priority and the division of the examination of the right of priority into two stages to be avoided. It is proposed also to regulate by which acts the right of priority is found or its loss is found, to provide an opportunity for appeal of the acts, which find a loss of right of priority by the special order, provided in article 69 of the Law on Marks and Geographical Indication, as well as to distinguish between the examination of the formal requirements and the material requirements of this right.

Zusammenfassung — Dieser Vortrag untersucht die Überprüfung des Prioritätsrechts im Registrierungsverfahren nach dem bulgarischen Markenrecht. Der Vortrag wirft die Frage nach Regelungslücken, unzureichender Regelung und Fragmentierung dieser Regelungen auf – alles Fragen, die das Unternehmen und sein Interesse am Registrierungsverfahren beeinträchtigen können. Eine vergleichende Analyse erfolgt mit dem Verfahren zur Eintragung einer europäischen Marke und der Prüfung des Prioritätsrechts nach europäischer Gesetzgebung. wirft die Frage nach Regelungslücken, unzureichender Regelung und Fragmentierung dieser Regelungen auf – alles Fragen, die das Unternehmen und sein Interesse am Registrierungsverfahren beeinträchtigen können. Eine vergleichende Analyse erfolgt mit dem Verfahren zur Eintragung einer europäischen Marke und der Prüfung des Prioritätsrechts nach europäischer Gesetzgebung. Basierend auf dieser vergleichenden Analyse unterbreitet der Autor Vorschläge zur Verbesserung der bulgarischen Gesetzgebung im Markengesetz, nämlich die Prüfung des Prioritätsrechts umfassend zu regeln und eine Zweiteilung der Prioritätsprüfung zu vermeiden. Es wird auch vorgeschlagen, zu regeln, durch welche Rechtsakte das Prioritätsrecht anerkannt oder sein Verlust festgestellt wird, um eine Möglichkeit zur Berufung gegen die Rechtsakte durch die in Art. 69 des Markengesetzes, sowie die Prüfung der formalen und materiellen Anforderungen dieses Rechts zu unterscheiden.

I. INTRODUCTION

According to Bulgarian legislation, as part of the formal examination of the trademark application, a check is carried out for the existence of a right of priority. This examination is essential for the applicant because it should establish an advantage in his favor over applications submitted after the date of the established right of priority. The finding of the examination may be relevant to the recognition and challenge of the substantive right of a trade mark. At the moment, there are gaps in the legislation regarding this examination and it is unnecessarily fragmented. This may affect the interests of the trademark applicant or the trademark owner.

The purpose of this report is to bring out some problematic issues of this examination in the Bulgarian legislation and on the basis of a comparative analysis with the European regulations to make proposals for its improvement.

II. EXAMINATION OF PRIORITY RIGHT– PROBLEMATIC ISSUES

An essential part of the formal examination of the trademark application is the examination of existence of right of priority. It establishes the existence of the right of convention priority and the right of exhibition priority.

In Art.46 "Formal Expertise" and the following from the Law of Marks and Geographical Indications (LMGI) [1] there are no provisions on when and how this inspection is carried out. However, such provisions exist in Ordinance for preparation, submission and expertise of applications for registration of marks and geographical indications (OPSEARMGI) [2].

The Bulgarian legislation divides the examination of the right of priority into two stages. In the first stage it stipulates that a fee must be paid for claiming the right of priority (as a formal requirement). According to Art.15, para 4 of

OPSEARMGI "if within the terms under para 2[1] the priority fee[2] is not paid, the applicant shall be notified that the priority is determined from the date of its filing ("date of filing of the application") with the Patent Office". Therefore, the non-fulfillment of the requirement for payment of a fee for the right of priority, leads to loss of the priority right. This is a very serious consequence for the applicant.

The second stage of this checking of the right of priority is part of a stage conditionally called "examination of other formal requirements to the application", (as the application has already passed the former stage of establishing the date of submission of the application and the verification of payment of fees under Art.46, para 1 of LMGI [1]). Pursuant to Art. 16, para 1, item 4, prop. 2 of OPSEARMGI [2], within one month from the submission of the document for paid fees[3] for each application it is checked whether it meets the requirements of Art. 10 of OPSEARMGI [2]. According to Article 10, para. 1 of OPSEARMGI [2] "in the claim for priority according to art. 45, para 2 of the LMGI [1] (convention priority - author's note) the date, the number of the first application and the country in which it was submitted shall be indicated in the application "According to Art. 10, para 2 of OPSEARMGI [1] "in case of a claim for exhibition priority according to Art. 45, para 4 of the LMGI [1], the application shall indicate the date of exhibition of the goods or services and the country in which the exhibition is organized. In addition, by argument of Art. 16, para 7 of OPSEARMGI [2], the inspection shall also cover whether a priority document has been attached, which meets the requirements of Art. 13 of OPSEARMGI [2]. According to Art. 13, para 1 of OPSEARMGI [2] "the priority document under Art.45, para 2, item 4 of the LMGI [1] (with regard to the conventional priority - author's note) represents a copy of the first application, certified by the competent authority of the country concerned." And according to Art. 13, para 2 of OPSEARMGI [2]. "The document under Art. 45, para 4, item 3 (with regard to the exhibition priority - author's note) is a certificate for participation in the exhibition, issued by the administration of the exhibition. The document shall also indicate the brand under which the goods and / or services were displayed. "

What is the result of this inspection, if the application does not meet these requirements, is stated again in OPSEARMGI [2]. According to Art. 16, para 7 of OPSEARMGI [2] "when priority is claimed and within the term under art. 45, para. 2, item 4 of the LMGI [1] (*as well as within the term under Art. 45, para 4, item 3 of the LMGI, should be added*) a priority document has not been attached or it does not meet the requirements of Art. 13, the applicant shall be informed that *the priority of the application is determined from the date of its filing with the Patent Office.* "Therefore, the consequence of this verification, if the conditions are not met, is again the loss of the right of priority.

So far, it can be generally said that this regulation of the right of priority is extremely incomplete and scattered.

First of all, this examination of the right of priority is essential for the trade mark registration proceedings and should find a place in the LMGI [1]. It is related to the finding of substantive consequences relevant to the applicant and therefore important to him.

Secondly, this dispersion of regulation, in different places in the LMGI [1] and in OPSEARMGI [2] (for example- Art. 42, para 3, item 10, art. 45, art.46, para 1 of LMGI [1], Art.10, Art.13, Art.15, para 4, Art.16, para 7 of OPSEARMGI [2]), it is necessary to be overcome.

Dividing this examination into two sages is a major complication for the applicant. He is placed twice facing the threat of losing the right of priority.

It is also necessary to regulate by which act the state expert who performs the examination recognizes or rejects the claim for the right of priority.

Last but not least, it is necessary to outline how the applicant can seek protection against the act of the state expert, by which the right of priority is not found, by removing this legal gap and explicitly regulating this issue.

III. EXAMINATION THE RIGHT OF PRIORITY IN EU

In a relatively legal aspect, the examination of the right of priority is envisaged to be under Art.41 of Regulation (EU) 2017/1001[4], entitled "Examination of the condition of filing". According to Guildelines for examination (European Union Intellectual Property Office) [5, p.242] – "If the priority claim is filed after the date of application of the European union Trademark (EUTM) and/or the priority claim or the priority documents fail to satisfy any of the other formal requirements, the applicant will be invited to remedy the deficiency or make observations within the time limit set by the Office." If the applicant does not respond or remedy the deficiencies, the consequences of non-compliance with the requirements of the right of priority will result in the loss of the right of priority. According to Art 41, point 6: от Regulation (EU) 2017/1001[4] "Failure to satisfy the requirements concerning the claim to priority *shall result in loss of the right of priority for the application.*"

In this regard is the regulation in Article 99 of Regulation (EU) 2017/1001[4] "Notification of loss of rights":„Where the Office finds that the loss of any rights (including loss of right of priority - author's note) results from this Regulation or acts adopted pursuant to this Regulation, *without any decision having been taken, it shall communicate this to the person concerned* in accordance with Article 98[4].The latter may apply for a *decision on the matter* within two months of notification of the communication, if he considers that the finding of the Office is incorrect. *The Office shall adopt such a decision only where it disagrees with the person requesting it; otherwise the Office shall amend its finding and inform the person requesting the decision*". The decision of loss of priority right is *appealable decision* according to Guildelines for examination (European Union Intellectual Property Office) [5, p.242, point 11.1.4].

The European regulation thus outlines an interesting legal construction of "loss of rights"[5]. With regard to the loss of the right of priority, it looks as follows:

1. The examiner finds loss of the right of priority for the application when the application does not satisfy the requirements concerning the claim to priority. Without a formal decision has been taken, the finding for the loss of right of priority must be communicated to the applicant.

2. If the applicant considers that the finding of the Office is incorrect, he may apply for a *decision on the matter (decision for loss of right of priority)* within two months of notification of the communication.

---

3. The Office, if it agrees with the person, shall amend its finding and inform the person requesting the decision.

4. The Office shall adopt a decision for loss of right of priority only where it disagrees with the person requesting it.

5. These decisions - findings of loss of rights are intended to be subject to appeal to a higher instance for review of legality.

I find this concept extremely practical and complete. It can be adopted and introduced in the LMGI [1]. This will create clarity and eliminate incompleteness in our legislation mainly with regard to the act - the decision (which does not find the right of priority in the trademark registration proceedings) and with regard to challenging this act. What could be the legal nature of these acts? Since they find facts of legal significance [7, p.12], it could be argued that these are ascertaining administrative acts. They could be from those ascertaining administrative acts, for which there is a procedural interest for their independent appeal. The issue is open and debatable.

In a relatively legal aspect, the examination of the right of priority reveals another feature.

The Guildelines for examination (European Union Intellectual Property Office) [5, p.241] clarify that the requirements in Art. 35 European Union Trademark Regulation (EUTMR) [4], with regard to convention priority are considered as "the formal requirements for priority claims". The formal requirements are considered to be: 1) priority claim filed together with the EUTM application; 2) number, date and country of the previous application; 3) availability of official online sources to verify the priority data, or submission of priority documents and translations, where applicable. The Guildelines for examination (European Union Intellectual Property Office) [5, pp.255-256] state that the formal requirements for priority claims for exhibition priority, according to the requirements in art 38, point 1, (last sentence) and point 2 EUTMR are 1) priority claim filed together with the EUTM application; (or subsequent to the filing of the EUTM application but still on the same day). 2) the name of the exhibition and the date of first display of the goods or services 3) a certificate issued at the exhibition by the responsible authority with special requirements. The essential thing is that according to Guildelines for examination (European Union Intellectual Property Office) [5, p.241] "at the examination stage, the Office *will only examine whether all formal requirements are met"*. Therefore, according to the European regulation, in the procedure for registration of European trademarks before European Union Intellectual Property Office, the concept discussed above refers to the decisions establishing the loss of the right of priority due to the fact that the formal requirements of the right of priority are not met.

For substantive legal prerequisites European legislation provides for them to be considered in a different order.

For the conventional priority the Guidelines for examination (European Union Intellectual Property Office) [5, p.242] provide that:

"The substantive requirements under Article 34 EUTMR will not be examined at the filing stage but during inter partes proceedings, where necessary, and will be restricted to the extent of the inter partes proceedings[6]". „The substantive requirements of the priority claim will be examined when the outcome of the opposition or cancellation case depends on whether priority was validly claimed."[7] The important thing here is that:"If the priority claim does not satisfy any of the above substantive requirements, the applicant will be invited to make observations within the time limit set by the Office. If the priority right could not be proved or appeared to be unacceptable, the priority right would be refused. *The outcome of the full examination would be reflected in the final decision on the opposition or cancellation proceedings.[8]"*

A similar situation is envisaged with regard to exhibition priority: "*the substantive requirements for exhibition priority will not be examined at the filing stage but during inter partes proceedings, where necessary, and will be restricted to the extent of the inter partes proceedings[9]"*

This puts the understanding of the examination of the right of priority in the Bulgarian legislation in a completely different way. From this point of view, the Bulgarian legislation in practice in the "formal expertise" examines only the "formal requirements" for the existence of the right of priority without examining the issue on the merits. And without the above comparative analysis, the opposite conclusion can be reached.

This different statement regarding the examination of the requirements of the right of priority according to the European Regulation is interesting with its advantages and it should be taken into account in the Bulgarian legislation. A comprehensive study of the right of priority and the regime for challenging that right is needed. The main advantage of this new for the Bulgarian legislation statement is that it guarantees to a higher degree the rights of the actual first holder of the right of priority.

---

6 According to Guidelines for examination (European Union Intellectual Property Office) [5, p.242] *The requirements that refer to the substance of the priority claims are covered by Article 34 EUTMR and relate to the 6-month period, the condition of a first regular filing and triple identity (same owner, same mark and same goods and services).*

7 The following situation are presented:

"1) In order to assess whether the trade mark on which the opposition (or invalidity request) is based is an 'earlier mark' or 'earlier right' within the meaning of Article 8(2) to (4) and (6) EUTMR. Determining the validity of the priority claim of the contested EUTM or earlier mark will be necessary when the relevant date of the earlier mark (its filing date or priority date) falls between the date of the claimed priority and the date of the filing of the contested EUTM. This will be assessed when the admissibility of the action based on that earlier right is determined.

2) In order to assess the admissibility of the request for proof of use (whether the earlier mark is subject to use or not). The assessment of the priority claim of the contested EUTM is necessary for determining the admissibility of the request for proof of use in inter partes proceedings when the 5 years from registration of the earlier right falls between the priority date of the contested mark and its filing date. Such examination does not preclude the re-assessment of substantive requirements in respect of the priority claim at the decision-taking stage if this is relevant for the outcome of the case.

3) In order to determine the period of use. It will always be necessary to examine priority in order to calculate the 5-year period to which proof of use must relate". Guidelines for examination (European Union Intellectual Property Office) [5, p.243]

8 See Guidelines for examination (European Union Intellectual Property Office) [5, p.246]

9 See Guidelines for examination (European Union Intellectual Property Office) [5, p.256]

IV. CONCLUSION

Therefore, as a conclusion from this analysis, the following can be summarized:

1) In the LMGI [1] it is necessary to comprehensively regulate the examination of the right of priority.

2) The dispersion of regulation, in different places in the LMGI [1] and in OPSEARMGI [2], it is necessary to be overcome. The regulation of the examination of the right of priority needs to be clearer and better systematized.

3) Dividing the examination of the right of priority into two stages is a major complication for the applicant (and twice puts him at risk of losing the right of priority). In the Bulgarian legislation, if it is preferred to remain the requirement for payment of a fee in respect of the claim to the right of priority, then let the examination of this requirement for payment of a fee be combined and performed with the examination of other formal requirements for establishing the right. It is also very important to give uniform instructions in case of non-compliance with the formal requirements for the right of priority and a general deadline for their removal.

4) To regulate by what act the right of priority is found and by what act it is found the loss of the right of priority. This can be done on the basis of the proposed concept of European legislation governing the institution of "loss of rights".

5) To provide an opportunity for appeal of the acts, which find the loss of the right to priority under the special order, provided in art. 69 of the LMGI [1].

6) To make the difference between the examination of the formal requirements and the substantive requirements of this right in the Bulgarian legislation and which ones are implemented at what stage. Although this issue is debatable, it deserves to be considered in detail, as it gives a better right of defense to the actual holder of the right of priority. This would ensure that the actual first holder of the right of priority could also be the first trademark owner.

In all these aspects, it is good to update and fill the gap in the Bulgarian legislation.

REFERENCES

[1] Law on Marks and Geographical Indications, State Gazette, No 98, December 13 2019, amendment and supplement to State Gazette No 92 October 27, 2020.

[2] Ordinance for preparation, submission and expertise of applications for registration of marks and geographical indications, adopted by a Decree of the Council of Ministers № 130 of 2 April 2021, promulgated State Gazette No. 28 of 6 April 2021 in force of 6 April 2021

[3] Tariff for fees, which are collected by the Patent Office of the Republic of Bulgaria, adopted by Decree of the Council of Ministers № 242 of 27.12.1999, promulgated in State Gazette No. 114 of December 30, 1999, in force since 30.12.1999, last amendment and supplement to State Gazette, № 18 of March 2, 2021

[4] Regulation (EU) 2017/1001 of the European Parliament and of the Council of 14 June 2017 on the European Union trade mark, OJ, L 154, 16.06.2017.
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1001&from=EN
(The page was visited on September 14, 2021).

[5] Guidelines for Examination (European Union Intellectual Property Office)
https://guidelines.euipo.europa.eu/1922895/1923283/trade-mark-guidelines/1-introduction
(The page was visited on September 14, 2021).

[6] Stefanova,D."Public legal aspects of the right of priority", Annual Scientific Conference 2012, The European future of Bulgaria, (legal aspects), Publishing complex – UNWE, pp 274-280.

[7] Lazarov, K, Administrative act - concept and types, Administrative justice, issue 2/1999, p.12

Claims of Priority Right

Anspruch auf Prioritätsrecht

Dimitrina Stefanova

Faculty of German Engineering Education and Industrial Management, Technical University -Sofia
8, Kliment Ohridski Blvd, BG – 1000, Sofia, Republic of Bulgaria, dimitrina.stefanova@gmail.com

Abstract — This report examines the right of priority from the standard point of view. Attention is paid to the formal and substantial prerequisites of the claims of priority (conventional priority claims and exhibition priority claims), according to Bulgarian legislation. A comparative analysis is made with the prerequisites of the claims for priority - conventional and exhibition, according to European legislation. Proposals for lightening of the formal requirements of the claims are made, including the introduction of an "implicit" claim to right of priority. The possibility of partially claiming the right of priority is being considered. The question also is asked whether right of priority under art. 45, para 1 of the Law on Marks and Geographical Indication is a kind of "national" priority. The author concludes that right of priority under art. 45, para 1 of the Law on Marks and Geographical Indications is a consequence of the date of submission of the application and gives arguments.

Zusammenfassung — Dieser Bericht untersucht das Prioritätsrecht aus einer Standardperspektive. Es wird auf die formalen und materiellen Voraussetzungen des Prioritätsanspruchs der Konventions- und Ausstellungspriorität nach bulgarischer Gesetzgebung geachtet. Es folgt eine vergleichende Analyse mit den Voraussetzungen des Prioritätsanspruchs der Konventions- und Ausstellungspriorität nach europäischer Gesetzgebung. Es wurden Vorschläge gemacht, die Formerfordernisse von Ansprüchen zu erleichtern, unter anderem durch die Einführung einer "impliziten" Geltendmachung des Prioritätsrechts. Die Möglichkeit einer teilweisen Inanspruchnahme des Prioritätsrechts wird geprüft. Die Frage ist, ob das Prioritätsrecht nach Art. 45 Abs. 1 LMGI eine Art „nationale" Priorität ist. Der Autor kommt zu dem Schluss, dass das Prioritätsrecht nach Art. 45 Abs. 1 LMGI sich aus dem Zeitpunkt der Antragstellung ergibt und liefert Argumente.

I. INTRODUCTION

A comprehensive study of the right of priority[1] has not been conducted in the Bulgarian trademark literature. In the patent law literature [2, p.157], it is considered as a civil subjective right. The view that the right of priority is a subjective civil right is also shared in the trademark literature [3].

There are different types of priority rights that are created by law. The main mentioned in Law on Marks and Geographical Indications (LMGI) [4] are "*the right of priority under international agreements*" and "*the exhibition priority*". These different named rights of priority arise from different complex factual compositions. These different complex factual compositions for the acquisition of the right of priority are discussed in detail in the trademark literature [5, p.55, 6, pp. 55, 56, 7, pp. 96, 97, 8, pp.183, 184]. Whether in this complex factual composition should be included the "decision – finding" on the right of priority of the state expert from the Patent Office? For the present I think yes, but for the future it depends of the future regulation of this right in the Bulgarian legislation and the future studies in the area.

The right of priority, according to LMGI [4] must be claimed (or declared) before the Bulgarian Patent Office. In the article the author will make a brief overview of the regulation of the formal and substantive requirement of the claims of the mentioned rights of priority - the right of priority under international treaties and of the right of the exhibition priority. Whether the regulated priority in Art 45, para 1 of the Law on Marks and Geographical Indications (LMGI) [4] is different type of priority will be placed.

This review will be made from a comparative point of view to serve to improve Bulgarian legislation[2].

II. RIGHT OF PRIORITY UNDER INTERNATIONAL AGREEMENTS

A. *Prerequisites for claims*

Article 45, paragraph 2 of the LMGI [4] regulates the right of priority based on international agreements. This priority is also known as "conventional priority"[2, p.157]. According to Art.45, para 2 of the LMGI [4] "The right of priority of *the applicant or his successor* is recognized from the date of a previous application, provided that:

1. The previous application has been lodged regularly in a Member State of the Paris Convention or of the World Trade Organization.

2. The previous application is *the first application* in the sense of art. 4 of the Paris Convention and is *for the same mark and for the same goods or services.*

3. The application shall be filed with the Patent Office *within six months from the date of filing* of the preceding application."

In a relatively legal aspect according to Guidelines for Examination [1, p. 242]: "The requirements that refer to the

---

1. According to Guidelines for Examination (European Union Intellectual Property Office (EUIPO)) [1, p.240]: "The principles of priority were first laid down in the Paris Convention for the Protection of Industrial Property of 20/03/1883, which has been revised several times and was last amended in 1979

2. On the website of the Bulgarian Patent Office, in the section for published decisions (https://portal.bpo.bg/legal_decisions), the author did not find separately classified decisions - findings for recognition or rejection of the right of priority

substance of the priority claims are covered by Article 34 EUTMR [9] and relate *to the 6-month period, the condition of a first regular filing and triple identity (same owner, same mark and same goods and services"*.

The procedural prerequisites of the claim for conventional priority are referred to in Art. 45, para 2, item 4 of the LMGI [4].

1. The claim for priority must be made with the submission of the application.

2. The claim must contain the date and country of the previous application (the data also include the number of the previous application - argument of art. 10, para 1 of OPSEARMGI [10]).

3. It is necessary to pay a state fee for priority (this fee can also be paid within the terms under Art. 46, para 1 of the LMGI [4]).

4. Within two months from the date of submission of the application, the applicant must submit a priority document issued by a competent authority of the country in which the previous application was submitted.

In a relatively legal aspect according to Art. 35, para.1, sentence 1 of the Regulation (EU) 2017/1001 [9]: "Priority claims shall be filed *together with the EU trademark application* and shall include the date, number and country of the previous application." In Art. 35, par.1, sentence 2 from the Regulation (EU) 2017/1001 [9] is stated that "The documentation in support of priority claims shall be filed within three months of the filing date". According to art.35, par.2 from the Regulation (EU) 2017/1001 [9] "The Commission shall adopt implementing act specifying the kind of documentation to be filed for claiming the priority of a previous application in accordance with paragraph 1 of this Article". It is interesting that according to art.35, par.3 from the Regulation (EU) 2017/1001 [9] *"The executive Director may determine that the documentation to be provided by the applicant in support of the priority claim may consist of less than what is required under the specifications adopted in accordance with paragraph 2, provided that the information required is available to the Office from other sources"*. Therefore, one characteristic feature of the European regulation is that it is aimed at minimizing the formal requirements for claiming the right of priority. Moreover, in EUIPO practice, it is accepted also *implicit* to make the claim to the right of priority. Thus, it can be accepted without an explicit claim of the priority right that the right of priority has been claimed. According to Examination Guidelines [1] "The claim may be implicit, such that the submission of the priority documents with the application or in a separate communication filed on the same date as the European Union trademark application will be construed as a declaration of priority. Simple filing receipts containing the country, number and date of the earlier application(s) are accepted" [1, p.241]. This decision seems right to me because it simplifies the formal requirements for the claims. In this way the cases in which the right of priority is lost because the claim for priority has not been formally made, will be avoided. However, to respect the legal logic that requires a claim to a right of priority to be done to be recognized, it is good to have a text in the LMGI [4] that a claim to a right of priority is made by filing the application or on the same day with a separate declaration. It can then be clarified that this claim is considered to be made "implicitly" if the application provides certain exhaustively listed data for the previous application or declaration with this data. Currently, in Article 42, paragraph 3, item 10 of the LMGI [4] does not contain as an element of the content of the application the claim for priority. It is specified in Art. 42, para 3, item 10 of the LMGI [4] that the application must

contain only "data for claimed priority, if is claimed, such". Does this mean that the Bulgarian legislator has regulated as a rule the implicit claiming of the right of priority? Rather, not. In this case, in Article 42, paragraph 3, item 3 of the LMGI [4] "the claim for priority, if is claimed, such" must be also included.

B. Partial assertion of the right of priority

The LMGI [4] does not explicitly regulate the so-called "partial priority[3]". In a relatively legal aspect Article 34, item 1 of Regulation (EU) 2017/1001 [9] regulates "partial priority", because the second application, which derives the right of priority, may contain some of the goods or services for which the first application is applied for. In Article 34, point 1 from Regulation (EU) 2017/1001 [9] is said that the right of priority shall be enjoyed "… in respect of goods or services which are identical with or *contained within* those for which the application has been filed". It can be said that even without it being explicitly regulated in the LMGI [4], if a priority is partially claimed (only about certain goods and/or services from the first application), it should be respected. Nevertheless, for better regulation in Bulgaria from the point of view of business and for facilitation in practice, the partial priority can be explicitly regulated.

III. DEFINITION OF THE RIGHT OF PRIORITY

There is no legal definition of the right of priority in the LMGI [4]. The clear definition of the right of priority makes an extremely good impression in the European regulations. According to Article 36 of Regulation (EU) 2017/1001 (Effect of priority right) [9] *"The right of priority shall have the effect that the date of priority shall count as the date of filing of the EU trademark application for the purposes of establishing which rights take precedence"*. The right of priority needs to be legally defined in Bulgarian legislation as well. The right of priority has a specific place and meaning in the proceedings for protection of objects of industrial property, for the registration of a trademark and it is better to be legally defined.

IV. EXHIBITION PRIORITY

Article 45, paragraph 4 of LMGI [4] regulates exhibition priority. According to Art. 45, para 4, items 1 and 2 of the LMGI [4], the right of exhibition priority of *the applicant or his successor* shall be recognized from the date of exhibition of the goods or services marked with the applied mark at an official or officially recognized exhibition, provided that: 1) the application is filed *within 6 months from the date of the first exhibition* of the goods or services, 2) the application is for the *same trademark and for the same exhibited goods or services*. §1 of the Additional Provisions of the LMGI [4] determines which is an "Official or officially recognized exhibition". Under §1 of the Additional Provisions of the LMGI [4], "Official or officially recognized exhibition" is an exhibition within the meaning of the Convention of 22 November 1928 for international exhibitions organized in the Member States of the Paris Convention, as amended. [8]

According to Art. 38 of Regulation (EU) 2017/1001 [9]: "If an applicant for an European Union trade mark has displayed goods and services under the mark applied for, at an official or officially recognized international exhibition falling within the terms of the Convention relating to international exhibitions signed at Paris on 22 November 1928 and last revised on 30

---

3. The partial priority is discussed on the patent law literature [2, p.162]

November 1972[4], he may, if he files the application within a period of six months of the date of the first display of the goods or services under the mark applied for, claim a right of priority from that that within the meaning of Article 36" (Effect of priority right - author's note).

The procedural prerequisites are pursuant to art. 45, paragraph 4, item 3 of the LMGI [4]:

1. The claim for priority is made with the submission of the application, indicating the date of the exhibition and the country in which the exhibition is organized

2. A state fee for priority has been paid (the priority fee may be paid within the terms under Art. 46, para 1 of the LMGI [4])

3. Within two months from the date of submission of the application, the applicant is required to present a document issued by the administration of the exhibition, proving the date of display of the goods or services marked with the mark applied for.

According to Art. 13, para 2 of LMGI [4] the document under art. 45, para 4, item 3 of the LMGI [4] is a certificate for participation in the exhibition, issued by the administration of the exhibition. The document shall also indicate the brand under which the goods and / or services were displayed.

Pursuant to Guidelines

"exhibition priority can be claimed either in the application or subsequent to the filing of the EUTM application but still on the same day.

The claim must include the name of the exhibition and the date of first display of the goods or services.

Within 3 months of the date of submitting the declaration of priority, the applicant must submit to the Office a certificate issued at the exhibition by the responsible authority. This certificate must state that the mark was in fact used for the goods or services, and indicate the opening date of the exhibition and, where the first public use did not coincide with the opening date of the exhibition, the date of first public use. The certificate must be accompanied by an identification of the actual use of the mark, duly certified by the authority."

Like the convention priority the claim may be implicit.

Therefore, the above conclusions regarding the claim of conventional priority are applicable.

V. RIGHT OF PRIORITY UNDER ART. 45, PARA 1 OF THE LMGI [4] OR A CONSEQUENCE OF THE DATE OF SUBMISSION OF THE APPLICATION?

Pursuant to Art. 45, para 1 of the LMGI [4] "The right of priority of the applicant over later filed applications for identical or similar trademarks intended for identical or similar goods or services shall be recognized *from the date of filing the application with the Patent Office*."

This norm is quite strange.

The question can be asked, is this a kind of "national" priority?

Indeed, I think that is not.

The arguments are:

The right of priority generally introduces *a point in time prior* than the date of filing the application - the "priority date"[5]. In the case of conventional priority, this earlier moment is the date of the filing of the "first application". In the case of exhibition priority, the earlier moment is the date of display of the goods or services at the specified exhibitions. If the right to a convention or exhibition priority is claimed and recognized,

this "priority date" (the earlier moment in time) *shall be equated with legal consequences to the filing date of the application* "for the purposes of establishing which rights take precedence" (if the definition of the right of priority of the Regulation (EU) 2017/1001 is used [9, art 36]). That is why, in my view, Art. 45, para 1 of the LMGI [4], *outlines the legal consequences of the date of filing the application*.

In addition, the LMGI [4] uses the term "date of filing the application" instead of "national priority" when the effect of the priority under Art.45, para 1 of LMGI [4] is applicable. For example:

The proprietor of an "earlier mark" may lodge an opposition under 52 of the LMGI [4] and to prevent the registration of a trademark filed after it in certain hypotheses of Art. 12, para 1 of the LMGI [4, art.12, para 1]. Defining the term "earlier mark", Article 12, paragraph 2 of the LMGI [4] clarifies that this is:

- Trademark, *with an earlier date of filing the application* or with an earlier priority, registered under this law, as well as

- Trademark applied for *with an earlier filing date* or with an earlier priority if it is registered under this law.

For these main reasons, I consider that the consequences of the "right of priority" under Article 45, paragraph 1 of the LMGI [4] are rather substantive legal consequences on the date of filing the application.

In a relatively legal aspect, this priority "over later applications" is not regulated by the Regulation (EU) 2017/1001 [9] as a type of right of priority.

VI. CONCLUSION

In this report, the author examines the prerequisites for claiming the right of priority and makes a brief comparative analysis of the right of priority with European legislation. Based on the analysis, several proposals for improving the Bulgarian legal framework can be derived and summarized:

1. To lighten the formal requirements for claiming the right of priority, including allowing the claim to be made implicitly.

2. To introduce a partial claim to the right of priority.

3. To give a legal definition of the right of priority in Law on Mark and Geographical Indications [4].

4. To connect the definition under Art. 45, para 1 of the Law on Mark and Geographical Indications [4] with the legal consequences of the date of filing the application.

All these proposals are in view of supplementing the Bulgarian legislation and its better implementation in practice.

REFERENCES

[1] Guidelines for Examination (European Union Intellectual Property Office)
https://guidelines.euipo.europa.eu/1922895/1923283/trade-mark-guidelines/1-introduction
(The page was visited on September 14, 2021)

[2] Pavlova, M., Patent Law of the Republic of Bulgaria, Sofia-R Publishing House, 2000

[3] Kostov, A. "Internal, conventional and exhibition priority for trademarks. Priority for Community trademarks"
https://iusauthor.com/publikacii/90-prioritet-pri-targovskite-marki.html

[4] Law on Marks and Geographical Indications, State Gazette, No 98, December 13, 2019, amendment and supplement to State Gazette No 92 October 27, 2020.

[5] Draganov, J., Legal regime of designations, Ciela soft and publishing - Sofia, 2006, p. 55.

[6] Sarakinov, G., Trademark Law in the Republic of Bulgaria, Sibi Publishing House - 2002, pp. 65-66

[7] Ilarionov P, Zlatareva, M., Trademarks, Ciela Soft and Publishing, Sofia, 2006, pp. 96-97,

---

4. According to Guidelines for examination [1, p. 256], these exhibitions are very rare and can be found on the following site: http://www.bie-paris.org/site/en/.

5. Regarding the "priority date" in patent literature [2, 157]

[8] Kamenova, Tsv. Stefanov, St., Kavrakova, M., Dekov, D., "Intellectual Property Law", "Intel Design" Ltd. - 2018, p.183-184

[9] Regulation (EU) 2017/1001 of the European Parliament and of the Council of 14 June 2017 on the European Union trademark, OJ, L 154, 16.06.2017.
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1001&from=EN
(The page was visited on September 14, 2021).

[10] Ordinance for preparation, submission and expertise of applications for registration of marks and geographical indications, adopted by a Decree of the Council of Ministers № 130 of 2 April 2021, promulgated State Gazette No. 28 of 6 April 2021 in force of 6 April 2021

[11] Convention of 22 November 1928 for international exhibitions organized in the Member States of the Paris Convention, as last amended on 30 November 1972

Droplet Formation Mechanism in Microfluidical Devices

Mechanismus der Tröpfchenbildung in mikrofluidischen Geräten

Emil Grigorov*

*Technical University of Sofia, Faculty of German Engineering and Economics Education,
e-mail: egrigorov@FDIBA.tu-sofia.bg

Abstract — The work presents a numerical study of the parameters influencing the droplet formation in a flow-focusing microfluidic device. The idea is to give an explanation for the mechanisms behind the emulsion formation in those type of systems. The utilized numerical method, volume-of-fluid (VOF) is validated against the results from an experimental study from the literature. After the validation was completed, the influence of the continuous phase velocity was studied in detail, revealing that with increasing value for u_c, droplet length reaches a point of saturation. The Ca number is introduced as a measure for the acting forces on the dispersed phase. The results revealed that for increasing capillary numbers Ca, above a value around 0,01 droplet size decreases noticeably and a transition from the dripping towards the jetting regime of droplet formation occurs.

Zusammenfassung — In der Arbeit wird eine numerische Studie der Parameter vorgestellt, die die Tröpfchenbildung in einer mikrofluidischen Vorrichtung beeinflussen. Die Idee ist, eine Erklärung der Mechanismen hinter der Emulsionsbildung in dieser Art von Systemen zu geben. Die eingesetzte numerische Methode, Volume-of-Fluid (VOF), wird mit den Ergebnissen einer experimentellen Studie aus der Literatur validiert. Nach der Validierung wurde der Einfluss der Geschwindigkeit der kontinuierlichen Phase im Detail untersucht, wobei sich zeigte, dass mit steigendem Wert für u_c die Tröpfchenlänge einen Sättigungspunkt erreicht. Die Ca-Zahl wird als Maß für die auf die dispergierte Phase wirkenden Kräfte eingeführt. Die Ergebnisse zeigen, dass mit zunehmender Kapillarzahl Ca oberhalb eines Wertes von $0,01$ die Tröpfchengröße deutlich abnimmt und ein Übergang vom Tropf- zum Strahlregime der Tröpfchenbildung stattfindet.

I. Introduction

In recent years, microfluidic devices have emerged as a novel tool for the realization of different biological and medical processes. The decreased reagents volumes, usually in the micro/nanoliters range, can significantly reduce reaction times and energy consumption for a certain process [1]. Droplet-based microfluidics, which encapsulates different chemical or biological compounds into individual picolitre-droplets, allows the isolation of reactions from their surroundings, protecting them from unwanted mixing and allowing better control over a massive number of independent reactions. These small microreactors have provided an easily implementable and relatively cheap approach for a broad range of processes including cell lysis [2], DNA purification [3], polymerase chain reaction (PCR) [4] and many more. Therefore, understanding the mechanisms behind the droplet generation is crucial for the efficiency of a droplet-based microfluidic systems. Droplets formation usually occurs when two immiscible liquids intersect each other. The process is achieved by passive (using pressure-driven flow and the channel geometry) methods. The specific design of the microfluidic channels makes it possible for an aqueous phase, usually water, to be sheared by another continuous phase (hydrocarbon oils, fluorocarbon oils etc. [5]) and produce uniform-sized drops. Different geom-
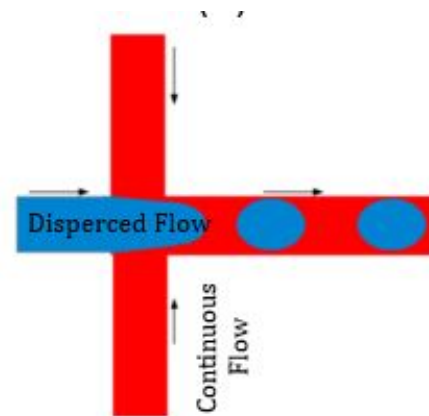

Fig. 1. Flow-focusing microfluidical setup for the droplet generation.

etry designs are possible, the most utilized in the praxis are: T-junction [6-7], flow-focusing [8-9], or co-flowing [10]. Figure 1 shows the flow-focusing device as an example.

For the design of microfluidic devices operating in droplet flow regime, prior knowledge of droplet size, shape, formation frequency or pressure drop are essential. A good way to collect in advance this information for a new setup is by utilizing a predictive CFD (Computational Fluid Dynamics) model and interpreting the influences of some fluid

properties on the droplet breakup. Few numerical studies on droplet-based microfluidics were carried out in the past years utilizing different numerical techniques (for example level set (LS) [11] or Lattice Boltzmann method (LBM) [12-13]). All these techniques show the usefulness of CFD methods as a valuable predictive tool. In this article we investigate numerically the droplet formation in a flow-focusing microfluidic channel by utilizing the volume of fluid (VOF) method. After a validation of the model, we make a parameter study on the effect of the continuous phase velocity. The droplet formation is investigated and analyzed by means of the capillary number Ca.

II. Mathematical model, geometrical setup and boundary conditions

In the present study three-dimensional simulations of droplet formation in a flow-focusing geometry are carried out utillizing a finite volume method based CFD solver from ANSYS Fluent 16. The two immiscible fluids, water and oil as well as their interface, are modelled by the Volume of fluid (VOF) method. In this method, following the Eulerian principle, the fluid flow is treated as a continuum. A phase fraction parameter, α, is used to indicate the presence of each phase at every location of the domain. Fluid properties such as viscosity and density are smoothed and the surface tension force is distributed near the interface as a body force in the Navier-Stokes equations. With this, the system of coupled partial differential equation consists of the continuity equation (1) the momentum balance equation (2), and the phase fraction equation for α (3) becomes [14]:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho U = 0 \tag{1}$$

$$\frac{\partial(\rho U)}{\partial t} + \nabla \cdot (\rho U U) = -\nabla p + \nabla \cdot (\mu[\nabla U + \nabla U^T]) + F_s \tag{2}$$

$$\frac{\partial \rho \alpha}{\partial t} + \nabla \cdot \rho \alpha U = 0 \tag{3}$$

In the equations above, U is the velocity vector field, p is the pressure field and μ the viscosity of the fluid. F_s represents the surface tension force

Only one such transport equation (3) needs to be solved since the volume fraction of the other phase can be inferred from the constraint:

$$\alpha_c + \alpha_d = 1 \tag{4}$$

where the index 'c' stands for continuous and 'd' for dispersed phase. The continuous phase (water) is introduced through the two side channels and the dispersed phase (oil: octane +2,5 % SPAN 80) is entered from the main (central) channel. The information about the fluid properties is obtained from the experimental results of Yao et al. [15]. All the measurements were conducted under atmospheric pressure conditions and room temperature.

For the boundary conditions, constant velocity block profile was utilized for both continuous and dispersed phase inlets. We set $\alpha = 1$ at the inlet of the dispersed phase and $\alpha = 0$ at the inlet of the continuous phase. No slip boundary conditions are applied at the walls. Pressure

TABLE I. Summary of the fluid properties

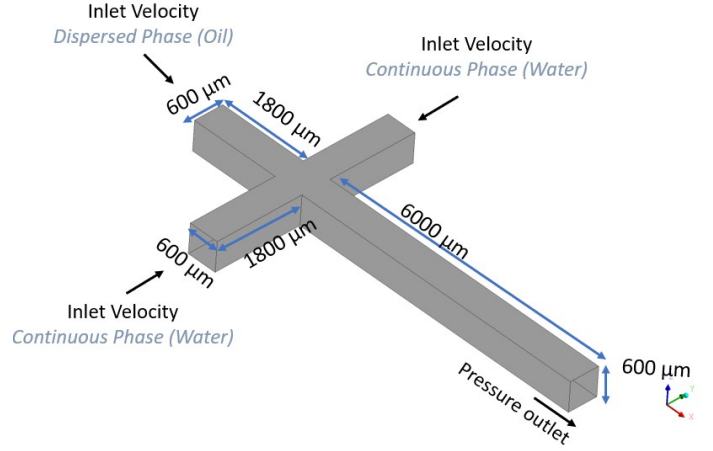| Fluid	Density ρ - [kg m^{-3}]	Viscosity μ - [mPa s]
Water	995,4	0,89
Oil	689,9	0,53

Fig. 2. Model geometry, dimensions and boundary conditions.

boundary was specified at the outlet of the main channel. Table 2 summarizes the varied boundary conditions for each case investigated. The inlet velocity of the dispersed phase (oil) was kept constant at $u_d = 0,0185 \, \mathrm{m \, s^{-1}}$ for all 4 cases. The surface tension coefficient between the two fluids is $\sigma = 5,37 \, \mathrm{mN \, m^{-1}}$. The lengths and dimensions of the square cross-section, the inlet and outlet channels are presented in Figure 2.

III. Results

In order to examine the efficiency of the VOF model, first a validation of the results with the experimental work of Wu et al. [16] is made. Numerical simulations was performed with the same fluid properties and channel dimensions, considered in the mentioned work (for more detailed information about geometry and fluid properties see the work of Wu et al. [16]). In this case water was utilized for the continuous phase and oil for the dispersed. Figure 3 shows the comparison of the droplet formation in the geometries in the two studies. It can be seen that both results have very close time scales regarding the generation of oil (blue) in water (red) droplets. First, the so-called filling stage is observed, where the dispersed phase is injected into the main channel. At some point the growing water-front blocks the flow from the side channels causing the upstream pressure to increase until it reaches a value where the continuous phase begins to squeeze the interface [17]. In the

TABLE II. Simulated cases

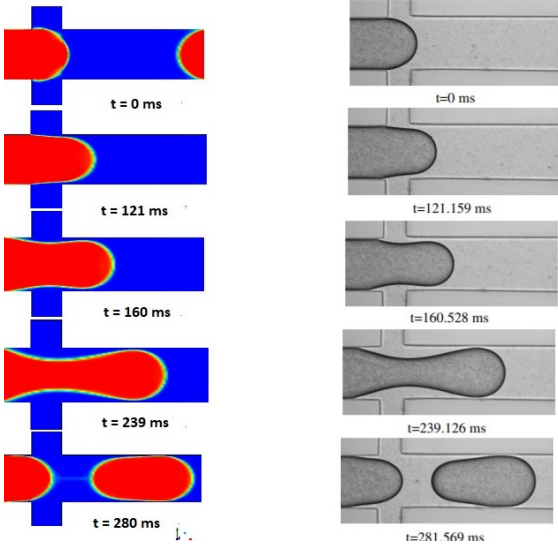| Case	u_c - [m s^{-1}]
1	0,0185
2	0,037
3	0,074
4	0,00925

Fig. 3. Visual Comparison between our results (left) and the experiment of Wu et al [16].

second, so called, necking stage the water is still being injected into the droplet at a constant flow rate, while the neck collapses. The collapse accelerates triggering the last pinch-off stage, where the droplet detaching occurs. The three stages described above form, the so-called dripping regime in a flow-focusing microfluidics device [18].

In order to understand better the mechanisms behind droplet formation in flow-focusing generator, four cases with varied continuous phase velocities (at constant dispersed flow rate of $u_d = 0,0185\,\mathrm{m\,s^{-1}}$) were carried out. The utilized geometry is shown in Figure 2.
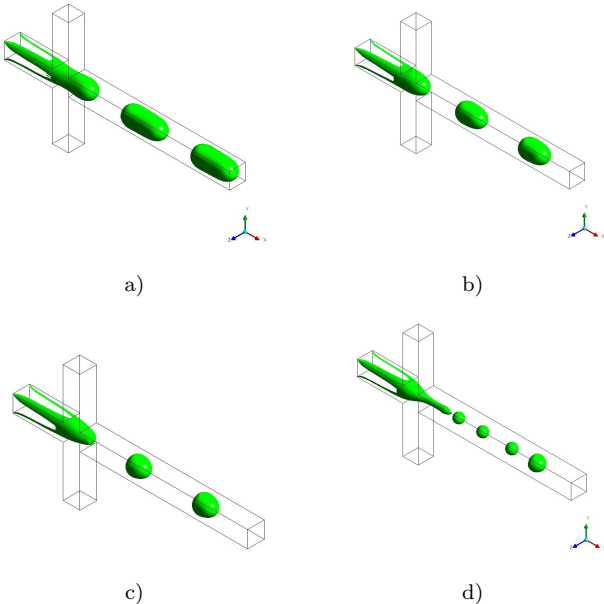

Fig. 4. Isosurfaces of the four simulated cases: a) $u_c = 0,009\,25\,\mathrm{m\,s^{-1}}$, b) $u_c = 0,0185\,\mathrm{m\,s^{-1}}$, c) $u_c = 0,0370\,\mathrm{m\,s^{-1}}$, d) $u_c = 0,0740\,\mathrm{m\,s^{-1}}$

The effect of velosity of the continuous phase gets noticeable in Figure 4. Higher continuous phase momentums disrupt the tendency of the surface tension to create few big droplets with less surface energy. Smaller droplets are therefore connected with bigger curvature radii and larger
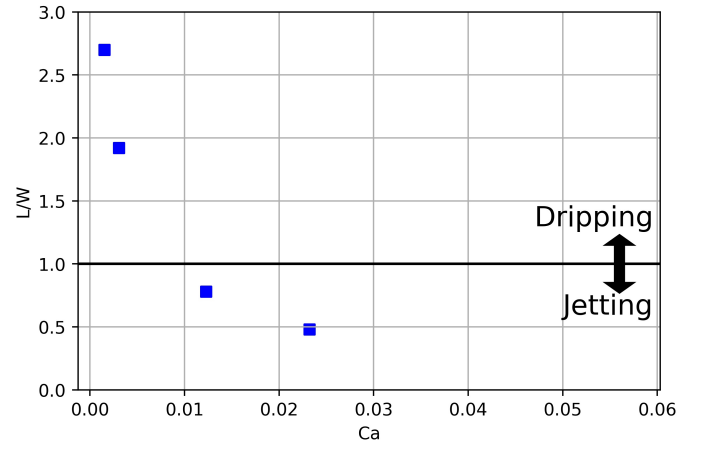

Fig. 5. The nondimensional lenght of the generated droplet as a function of the Ca number.

differences in the pressure jumps between the inside and the outside of a single droplets. It is also clear that smaller droplets creation occurs at higher frequencies. The 'cutting' shear force on the droplets increases at higher velocity ratios, thus making the length of the droplet to decrease. In this, so called jetting regime, a long-suspended column of the disperse fluid flows at the tube as shown in Figures 4d). Naturally, there is a lower limit to the size a particular device can achieve and this is based upon the physical size and individual geometry of that particular device.

One of the critical parameters thoroughly investigated in droplet producing microfluidic devices is the capillary number, described in Equation 5:

$$Ca = \frac{u_c \mu_c}{\sigma} \qquad (5)$$

where $_c$ is the dynamic viscosity of the continuous phase. The number identifies the ratio of viscous to interfacial forces. For low capillary numbers, capillary tension dominate leading to the formation of big droplets. Similar to the Reynolds (Re) number, the Ca number can be used to determine a transition-boundary between two flow regimes. One way to do this is to show the geometrical changes in the generated droplets as a function of Ca. Figure 5 shows the non-dimensional length of the droplets (ratio between the lenght of the droplet L and the width of the chanel W) for the 4 cases as a function of the Capillary number. In the Figure it can be seen that the largest changes of the drop size occur up to $Ca \approx 0,01$. The transition between the two main flow regimes - dripping and jetting - occurs at $\frac{L}{W} \approx 1$. There is an indication that for even larger Ca numbers the droplet size does not change significantly.

IV. CONCLUSION

In this work the droplet generation in a flow-focusing microfluidic device has been investigated. The continuous phase (water) was introduced through the two side channels and the dispersed phase (oil: octane +2,5 % SPAN 80) was entered from the main channel. For all simulations the VOF method was utilized. After a validation of the model was carried out, the investigation of the influence of different velocities of the continuous phase on the droplet formation was simulated. Two flow regimes are formed –

dripping and jetting, which are distinguished by the size of the droplet (for jetting droplets are smaller than the width of the channel). The transition between these regimes is investigated. This is done for a wide range of velocities u_c ($0{,}0740\,\mathrm{m\,s^{-1}} > u_c. > 0{,}009\,25\,\mathrm{m\,s^{-1}}$). There is a critical Ca number, which serves as a transition point between the two described flow regimes (dripping and jetting). For the cases with water as a continuous phase, a critical value of around $Ca \approx 0{,}01$ is observed. As a whole, the present study shows that the VOF method is a reliable technique for the simulation and prediction of droplet generation in a flow-focusing channels. It will allow the future study of other diverse setups and various fluid combinations.

REFERENCES

[1] N. Nguyen and S. Wereley, *Fundamentals and Applications of Microfluidics*; Artech House Publishing: Norwood, MA, USA, (2007), 3rd ed. Harlow, England: Addison-Wesley,

[2] E. Grigorov, B. Kirov, M. Marinov and V. Galabov *Review of Microfluidic Methods for Cellular Lysis*, vol. 12, Micromachines 2021, 498

[3] Y. Xu, Z. Zhang, Z. Zhou, X. Han and X. Liu,*Continuous Microfluidic Purification of DNA Using Magnetophoresis*,vol. 11, Micromachines 2020, 187

[4] B.K. Madhusudan, G. Sanket,*Advances in continuous-flow based microfluidic PCR devices—a review*, vol. 2, Eng. Res. Express 2020, 042001

[5] N. Shembekar, C. Chaipan, R. Utharala and C. A. Merten *Droplet-based microfluidics in drug discovery, transcriptomics and high-throughput molecular genetics*, vol. 16, Lab Chip 2016, 1314-1331

[6] T. Thorsen, R. W. Roberts, F. H. Arnold and S. R. Quake *Dynamic Pattern Formation in a Vesicle-Generating Microfluidic Device*, vol. 86, Phys. Rev. Lett. 2001, 4163—4166

[7] W. Zeng and H. Fu *Precise droplet formation in a T-junction micro-droplet generator*, vol. 86, IEEE 8th International Conference on Fluid Power and Mechatronics (FPM) 2019, 1190-1196

[8] S. L. Anna, N. Bontoux and H. A. Stone *Formation of dispersions using "flow focusing" in microchannels*, vol. 82, Appl. Phys. Lett. 2003, 364—366

[9] L. Yobas ,S. Martens, W. L. Ong and N. Ranganathan *High-performance flow-focusing geometry for spontaneous generation of monodispersed droplets*, vol. 6, Lab Chip 2006, 1073 —1079

[10] C. Cramer, P. Fischer and E. J. Windhab *Drop formation in a co-flowing ambient fluid*, vol. 59, Chem. Eng. Sci. 2004, 3045—3058

[11] W. Lan, S. Li, Y. Wang and G. Luo *CFD Simulation of Droplet Formation in Microchannels by a Modified Level Set Method*, vol. 53, Ind. Eng. Chem. Res. 2014, 4913

[12] Y. Li, M. Jain, Y. Ma and Nandakumar *Control of the breakup process of viscous droplets by an external electric field inside a microfluidic device.*, vol. 11, Soft Matter 2015, 3884

[13] A. Gupta, H. S. Matharoo, D. Makkar and R. Kumar *Geometry Effects of Axisymmetric Flow-Focusing Microchannels for Single Cell Encapsulation*, vol. 100,Comput. Fluids 2018, 218

[14] C. Yao, Y. Liu, C. Xu, S. Zhao and G. Chen, *Formation of Liquid-Liquid Slug Flow in a Microfluidic T-junction: Effects of Fluid Properties and Leakage Flow*, vol. 64, AIChE J. 2018, 346

[15] K. Ghaib *The Volume of Fluid Method, a Method for the Simulation of Two-Phase Flow* , Chemie Ingenieur Technik 2018, 316-323

[16] L. Wu, M. Tsutahara, L. S. Kim and M. Ha, *Three-dimensional lattice Boltzmann simulations of droplet formation in a cross-junction microchannel*, vol. 34,Int. J. Multiphase Flow 2008, 852

[17] P.A. Romero and A.R. Abate *Flow focusing geometry generates droplets through a plug and squeeze mechanism*, vol. 12, Lab Chip 2012, 5130-5132

[18] X. Chen, T. Glawdel and N. Cui *Advances in Droplet-Based Microfluidic Technology and Its Applications*, vol. 18, Microfluid Nanofluid 2015, 1341–1353

Authors Index