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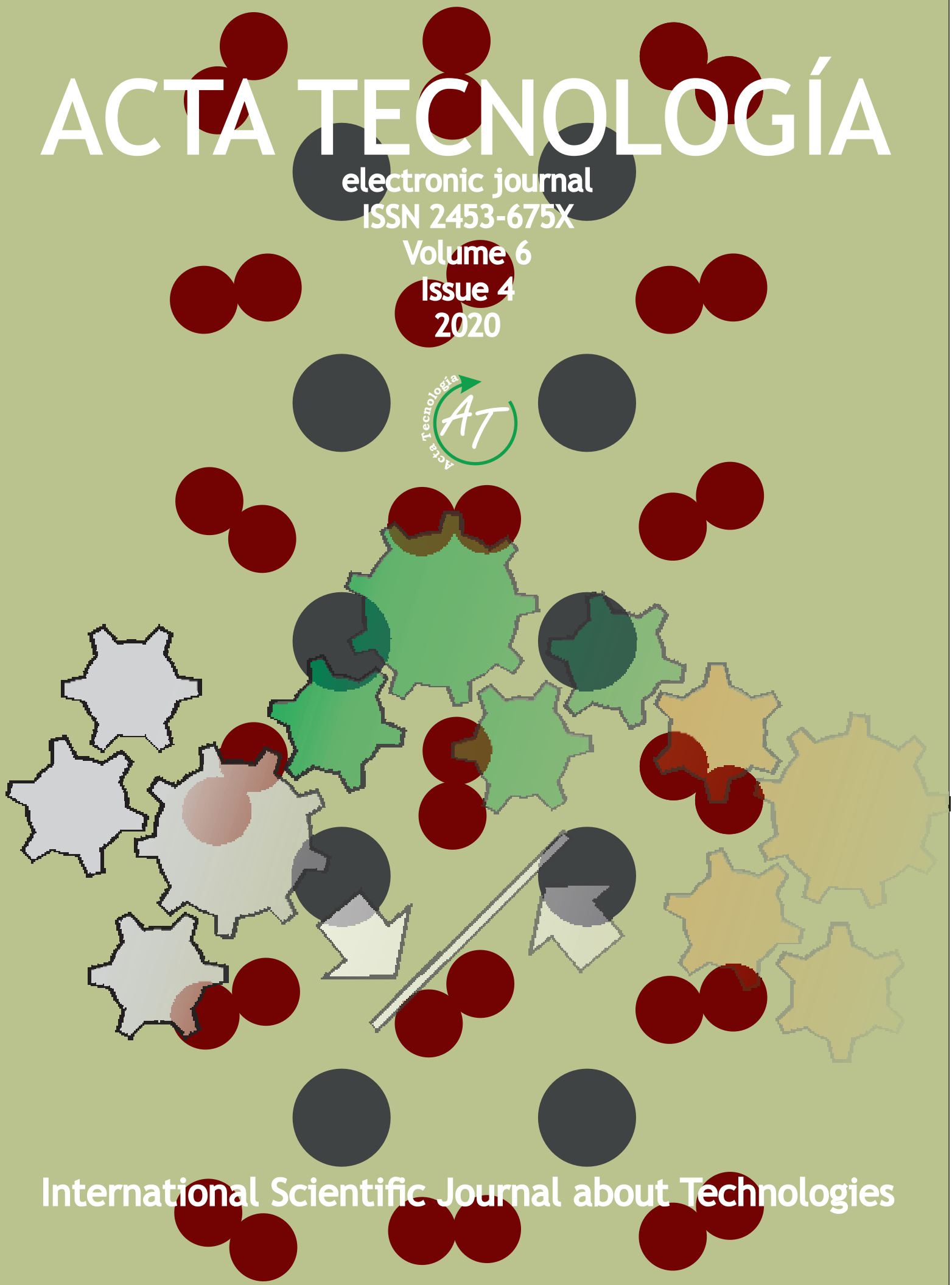

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CONTENTS
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THE DIGITAL ECOSYSTEM AND ENTREPRENEURIAL MUSIC DISTRIBUTION: A FORCE FIELD PERSPECTIVE

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Keywords: digital music distribution, entrepreneurship, electronic distribution, disintermediation, music distribution
Abstract: The world of business has evolved from the 19th century (steam, rail and electricity) to the 20th century (telephone, radio, television and, especially, the computer as the greatest information technology that converts analogue signals into a digital form including binary digits), and the 21st century (the fourth industrial revolution (4th IR) – described as the advent of "cyber-physical systems" involving entirely new capabilities for people and machines). Digital entrepreneurship is an emergent phenomenon in which new digital artefacts, platforms and infrastructure are used to pursue innovative and entrepreneurial opportunities, which, to a certain extent calls into questions the relevance and applicability of traditional understandings of entrepreneurship. The study on which this article is based investigated digital entrepreneurship's impact on the dynamic social networking market in light of the infusion of disruptive and innovative technology. It aimed to determine the entrepreneurship capability and competence that impact on digital music change management; and to examine the extent to which digital music distribution balances the driving forces of digitisation and the restraining forces from disruptive technology. An exploratory research design was adopted using univariate, bivariate and multivariate statistical analysis techniques to analyse the data collected from 217 musicians. The study found that the Internet is capable of reliable delivery of music processes, products and services, thereby enhancing supply chain distribution competence and capability. Digital entrepreneurial innovations enable independent artists to create music according to their tastes and customer demand. Independent music production and creation drive the economic entrepreneurial dimension while technological advancements encourage digital independent music distribution.

1 Introduction

Traditional entrepreneurship creates new enterprises by commercialising products and services, while digital entrepreneurship pursues new venture opportunities using the new media and Internet technologies that have emerged during the 4th IR (industry 4.0). The entrepreneur always searches for change, responds to it, and exploits it as an opportunity. A digital entrepreneur is therefore an individual who creates and delivers key business activities and functions using information and communication technologies (ICTs). The development of entrepreneurial and digital competencies (EDCs), coupled with policy interventions, requires improved ICT infrastructure, distribution infrastructure, and effective training opportunities to produce competent and productive digital entrepreneurs (Ngoasong, 2018:1). This article examines the digital ecosystem of music entrepreneurship from the perspective of the force field theoretical context. This theory holds that the outcomes of any situation are a function of interacting and interdependent connected elements or actors, with one element or actor having the ability or tendency to influence the situation. The entrepreneurial ecosystem is a new way to contextualise the increasingly complex and interdependent social systems created through self-organisation, scalability, and sustainability. An Online Social Network (OSN) is a contemporary Internet phenomenon where everyone and everything is connected. Its purpose ranges from social relations to material and resource sharing, daily activities, and keeping track of developments. Social media platforms enable digital entrepreneurs to build and expand social and professional networks with different stakeholders and music fans within and beyond geographic territories using a variety of modalities (Valkenburg, Koutamanis, & Vossen, 2017). Social networks include websites and applications that allow stakeholders – users, fans and music businesses – to share content, ideas, opinions, beliefs, feelings, and personal, social, and educational experiences. The emergence of blockchain, virtual reality and artificial intelligence has facilitated and improved the quality of global music production, distribution, performance and communication, sometimes resulting in a form of cyber-relationship addiction (Pentland, 2016; Can & Kaya, 2016; Avcı, Çelikden, Eren & Aydenizöz, 2015). Virtual Reality (VR) technologies include VR headsets and VR-enabled smartphones, among others such as virtual performances. Blockchain provides a record of all dealings transversing a peer-to-peer network. Its usage includes transferal of funds and a streaming music online ledger, without a bureaucratic endorsing authority like a record company or

a bank. The Internet of Things (IoT) includes gadgets with built-in sensors, software and network connectivity and is used to gather, interchange and act on data, normally without human involvement. Nambisan (2017:1029) emphasises that "digital music distribution and consumption cycles through social media and other digital platforms by different entrepreneurs lead to different types of effectual cognitions and behaviours and outcomes." The generativity induced by digital music platforms shapes the dynamic emergence of novel and embryonic profitable entrepreneurial opportunities and growth prospects. Parker, Van Alstyne and Choudary (2016: n.p.) describe a digital platform as "a shared, common set of services and architecture that serves to host complementary offerings, including digital artefacts".

2 Background to the study

The advent of technology that enabled independent music creation changed the music industry's landscape. Bacache, Bourreau and Moreau (2014:2) observe that digitalisation has reduced the cost of a self-releasing strategy or music entrepreneurship and allowed digital-enabled small independent labels to enter the industry (Waldfoel, 2012). Digital home studios virtually eliminate recording costs (Bacache, Bourreau & Moreau, 2014; Fox, 2004; Waldfogel, 2012) and distribution costs are negligible. New opportunities for online promotion have emerged, allowing artists to promote their music on websites or social media networks. The International Federation of the Phonographic Industry (IFPI) (2014) and Vermeulen (2014) note that in 2010, digital music accounted for 29% of global music sales and that in 2013, South Africa was ranked 17th for physical format sales and 26th in overall world rankings. The contraction of physical production and consumption of music has economic effects on record labels while musicians are presented with a golden opportunity to invest in digitisation for self-sustaining careers. The entrepreneurial appetite and mindset should serve as an impetus for a reconfigured economic dimension. This article discusses the transformed working practice associated with the contemporary entrepreneurial discursive context that promotes the success of independent musicians through digitisation. For the first time ever, streaming music revenue surpassed income from the sale of traditional platforms such as CDs in 2017. South Africans have numerous music streaming platforms to choose from, all with nearly identical offerings at the same price. They include Spotify (R59.99 – 35m song catalogue), Joox (R59.99 – 3m song catalogue), GooglePlay (R59.99 – 40m song catalogue), Simfy Africa (R60.00 – 24-hour radio channel for new music), Deezer (R59.99 – personalised stream – flow), and Tidal – Jay-Z (R135.00 48.5m music tracks per month) (De Villiers, 2018). The 4th IR's effects on society and the economy (Prisecaru, 2016:57-62) mean that many people around the world are likely to use social media platforms to connect, learn and exchange information.

3 Research problem and objectives

The speed, breadth and depth of the 4th IR revolution, in which technology is transforming our world, is forcing us to rethink how countries develop, how organisations create value and even what it means to be human. The business enterprise model is characterised by a confluence, convergence, and fusion of technologies that is blurring the lines between the physical, digital, and biological spheres. The reasons why today's transformations are distinct include their velocity (evolving at an exponential rather than a linear pace), scope (breadth and depth – unprecedented paradigm shifts in the economy, business, society and individually), and systems impact (transformation of entire systems across (and within) countries, companies and society as a whole). Technology and the Internet have spawned three related disruptions which have undermined the financial viability of the traditional supply chain, including Internet retailers (leading to global closure of retail music shops), direct digital distribution (creating entrepreneurship); and theft or piracy (legal online stores like iTunes / Digital Rights Management). Digital music devices as device convergence facilitate communication with fans, storage of online music and nimble production of music tracks by processing information and offering information services as network convergence. Market convergence through digitised global reach and repositioned social media facilitate the entrepreneurial music process of convergence. The digital social network uses the term imbrication as a way of specifying an interaction that is not characterised by hybridity or blurring but involves social digital networks with global span to reach diversified fans.

This article investigates digital entrepreneurship's influence on the dynamic social networking market given the infusion of disruptive and innovative technology, to determine the entrepreneurship capability and competence that impact on digital music change management. It examines the interrelationship between the driving forces of digitisation and the restraining forces of disruptive technology in digital music distribution. The main aim is to interrogate the infusion of digital music production and distribution cycles into the aspects of creative labour, innovation and entrepreneurship that have shifted the nature and unique characteristics of entrepreneurial processes and outcomes from discrete romantic individualism to an impermeable mere creative sector. The entrepreneurial narratives of opportunity are shared and co-created through social networking and enacted in an increasingly digital world, with interactions on digital forums with fans, sponsors and supply chain partners.

3.1 The concept of entrepreneurship

The concept of entrepreneurship is derived from the French word "entreprende" which means "undertake"

(Carton, Hofer & Meeks, 1998). Entrepreneurship has been the focus of different disciplines such as economics, sociology, finance, history, psychology and anthropology, each of which works with its own terms (Low & MacMillan, 1988). Shane and Venkataraman (2000) define entrepreneurship as the use of opportunities for the discovery, evaluation and promotion of goods and services, forms of organisation, markets, processes and raw materials that were not previously available. In the 20th century, Joseph Schumpeter asserted that entrepreneurship requires innovation and that entrepreneurs are responsible for doing new things or doing things in a new way. Leibenstein took this further by stating that entrepreneurs drive change drawing on abilities such as leadership, motivation, solving crises and taking risks (Parker, 2004). Finally, McClelland touched on personal and psychological characteristics, emphasising that individuals exhibit certain behaviours based on their needs such as establishing close relationships, obtaining power and achieving success (Iraz, 2010). Entrepreneurship plays an important role in many sectors, notably the tourism industry (Çalkın & Işık, 2017), and has contributed to economic stability, growth and prosperity (Özdevecioğlu & Karaca, 2015); national income and employment (Küçükaltan, 2009) and to personal development and solutions to social problems (Ball, 2005).

Pietila (2009) and Waldfoel (2012) note that digitalisation has enabled small independent labels to enter the music industry and has promoted music entrepreneurship. The introduction and on-going development of digital technologies provide musicians with the tools they need to be truly independent; hence, innovation inspires independent music entrepreneurship. Recording can now be performed in digital home studios using hardware (a computer) and software (an audio sequencer or digital instruments). Digital technologies have democratised music production by making traditionally expensive and specialised in-house activities accessible and a wider range of talents has been exposed. Technological developments have removed the traditional barriers of cost and skills. Dewenter, Haucap and Wenzel (2012) and Karubian (2009) note that 360-degree deals mean less control for the artist, as all his/her activities are controlled by a single company. The 360-degree contract or equity deal is the opposite of the self-releasing strategy as the musician interacts across the entire supply chain when engaging in the self-releasing strategy or music entrepreneurship (Bacache, Bourreau & Moreau, 2014; Suede, 2014). If musicians want to charge consumers for their music, they can register with Apple iTunes to license it and be paid a fee while gaining international exposure with no geographical boundaries.

3.2 Digitisation and entrepreneurship

The digital world of business requires infrastructure in the form of cyber, physical and organisational-based structures for supply chain operations of the network, extended enterprises and service-based facilities. Tilson, Lyytinen and Serensen (2010:748) define digital infrastructure as "the basic information technologies and organisational structures, along with the related services and facilities necessary for an enterprise or industry to function". The authors distinguish "digitising as technical process, from digitisation as sociotechnical process of applying digitising techniques to broader social and institutional contexts that render digital technologies infrastructure". A digital entrepreneur is defined by Hair, Wetsch, Hull, Perotti and Hung (2012: n.p) as "an individual who creates and delivers key business activities and functions, such as production, marketing, distribution and stakeholder management, using information and communication technologies". Digitisation of products and services allows for greater flexibility by separating function from form and content from medium (Yoo, Henfridsson, & Lyytinen, 2010), rendering entrepreneurial outcomes "intentionally incomplete" (Garud, Jain, & Tuertscher, 2008) – that is, the scope, features, and value of offerings continue to evolve even after they have been introduced to the market or 'implemented'. Digitisation of entrepreneurial processes has helped to break down the boundaries between the different phases and brought greater levels of unpredictability and nonlinearity to how they unfold (Garud, Gehman & Giuliani, 2014). Nambisan (2017:1030) reflects that digitisation has led to less predefinition in the locus of entrepreneurial agency (that is, where the ability to garner entrepreneurial ideas and the resources to develop them is situated) as it increasingly involves a broader, more diverse, and often continuously evolving set of actors – a shift from a predefined, focal agent to a dynamic collection of agents with varied goals, motives, and capabilities (Nambisan & Zahra, 2016), including the new types of digital infrastructure such as crowdfunding systems that host complementary offerings (Parker, Van Alstyne, & Choudary, 2016). The emergence of digital entrepreneurship has reignited debate on meritocratic and unbounded opportunities (Martinez Dy, Marlow & Martin, 2017), given that virtual exchanges facilitate access by reducing both entry costs and stereotypical discrimination (Daniels, 2009). This constructs the ideological foundation for a 'digital enterprise discourse' whereby access to digital platforms and encouragement of entrepreneurial behaviour is assumed to empower people to embrace the entrepreneurial promises of freedom and flexibility (Jones, 2017), enhance their personal socio-economic circumstances (Thompson Jackson, 2009) and contribute to the national economy (Schmidt, 2011). Extant business and management literature on digital entrepreneurship implicitly reflects on creating economies of scale and electronic creation of value as expected entrepreneurial benefits (Giones & Brem, 2017; Sussan & Acs, 2017).

3.3 Theoretical framework

Theories are formulated to clarify, anticipate, and fathom phenomena as well as to challenge and grow existing knowledge. The theoretical framework is "the structure that can hold or support a theory of a research study. … [It] displays and delineates the theory that clarifies why the research problem … exists" (Gabriel 2013:25).

The growth of the Internet raises vital questions about how individuals decide whether and when to adopt an innovation, and how the innovation will be diffused among the population. Diffusion is "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003:5; Hornor, 2008:1). According to Rangaswamy and Gupta (1999:1), the study of adoption behaviour and the diffusion process for digital products is based on the concepts and theories of individual decision making and allows one to segment and profile customers based on the time of adoption and on their inclination to adopt an innovation. The Diffusion of Innovation theory focuses on how, why and at what rate novice ideas and technology are disseminated across cultures and generations for music entrepreneurs to seize the opportunity of digital distribution. The theory posits that, as time passes, an idea or product gains market share and spreads in a specific social system. The digital social network uses the term imbrication as a way of specifying an interaction that is not characterised by hybridity or blurring, but social digital networks with global span to reach diversified fans. Social network theory explains the communication and interaction harnessed to create and sustain social value in the context of social entrepreneurship. In terms of cyber-relationship addiction (Can & Kaya, 2016), the theory of behavioural explanation holds that, a person uses social networks for rewards such as escaping reality and entertainment in relation to hedonic and service experience. Many theories have been developed over time that offer explanations for the emergence of new technological systems in terms of diffusion, acceptance and benefit and also explain why some users become addicted to using certain technologies or become dependent upon them (Ajjan & Hartshorne, 2008). The Technology Acceptance Model (TAM), an extension of the Theory of Reasoned Action (Davis, 1989; Fishbein & Ajzen, 1975) predicts the primary motivational factors for the use and acceptance of new technologies and systems as "the degree to which an individual believes that using a new technology or an information system would enhance his or her productivity". Force field analysis is a change management technique which was originally conceived by psychologist Kurt Lewin for use in social situations. It displays and analyses the forces driving movement towards a goal (helping forces) or restraining movement towards it (hindering forces). Lewin (Catwright, 1951) explains that the result of any situation is a function of interacting and interdependent connected elements or actors; that is, the ability or tendency of one element or actor to influence the situation which is called a 'field' (Dubey, 2017: 701). Change arises due to an imbalance between the driving forces (new personnel, changing markets, new technology) and restraining forces (individual fear of failure, organisational inertia). The force field theory suggests that driving forces (the external threats of independent labels combined with internal benefits) must exceed the resisting forces (culture, structure, perceptions of how things should be done). Bridges (2017) argues that, driving change effectively implies helping individuals to grasp the difficulties to the point that they positively acknowledge and psychologically own better approaches. The framework enables a balance of driving and restraining forces where the digital entrepreneur interacts and interrelates with fans at a more in-depth level which is called the macro level (the field or digital platforms) and social networking (Dubey, 2017: 700-701).

3.4 The digital entrepreneurship ecosystem

In the wake of the rapid advancement of digitisation and the impact of digitalisation the concept of digital ecosystems has been scrutinised and defined from an array of perspectives, ecological, economic, and technological (Li, Badr, & Biennier, 2012), and has attracted multi- and interdisciplinary discourses (Dini, Iqani & Mansell 2011). The digital ecosystem (DE) can be applied in business, knowledge management, services, social networks, and education. It is defined as a business model for a self-organising, scalable and sustainable system composed of heterogeneous digital entities and their interrelations focusing on interactions among entities to increase system utility, gain benefits, and promote information sharing, inner and inter cooperation and system innovation (Li, Badr, & Biennier, 2012:119). The entrepreneurial ecosystem is also a new way to contextualise the increasingly complex and interdependent social systems being created that are characterised by self-organisation, scalability, and sustainability. According to Sussan and Acs (2017:56), the Digital Entrepreneurial Ecosystem framework consists of four concepts: digital infrastructure governance, digital user citizenship, digital entrepreneurship, and the digital marketplace.

4 Supply chain music distribution

For a musician, the artistic value of authenticity reflects the romantic measure of truth embedded in the inner feelings of unique human creativity, innovation and skill. The musician's romantic individualism does not hide behind the narrative; rather, the dexterity of art and baring of flaws mark the authenticity as the sign of an honest connectivity with global loyal fans. Digital platforms and networks create efficient and effective circulation of romantic framing for genuine music. Sociodigital technologies facilitate the creation and maintenance of extended networks, cultivating technological fluency, and participation in passionate interest communities and

networks with global span. The essence of romantic individualism framed from the value of innovation and the creative impetus transforms and demystifies the musician into a business entrepreneur who is driven by the profit motive. According to Xu, David and Kim (2018), the 4th IR has created opportunities for digital entrepreneurs with new ideas to establish independent music companies with lower start-up costs and a more active role for artificial intelligence (which offers new avenues for the economic growth of the music business). New markets are created and new business models are defined, where Netflix is competing with traditional television, brick and mortar music stores are competing with streaming platform enterprises such as Spotify, Deezer, Simply, Google play, Tidel, etc., and music labels on analogue are competing with YouTube and iTune for album/track releases. Alves (2004:6) concurs with Lam and Tan (2001:64) that peer-to-peer sharing across the Internet causes the disintermediation of record companies and retailers from the traditional supply chain and enables artists and consumers to be directly connected through websites and peer-to-peer sharing technology. It is important to emphasise that disintermediation occurs when online music websites such as MP3.com, Napster, eMusic, Rhapsody and the multitude of other online music stores provide free services for customers to download and upload digital music files from peer-sharing websites (Bernardo & Matins 2013:4). Free or easier acquisition of digital music led to a significant decrease in album sales internationally and locally which ultimately resulted in the closure of retail music shops (Bielas, 2013; Look & Listen, 2014; McIntyre, 2009; Shevel, 2014; Stensrud, 2014; Warr & Goode, 2011). Bernardo and Martins (2013:3) explain that in economics, "an intermediary is a third party that offers intermediation services between two trading parties", namely a supplier and a consumer. Chircu and Kaufman (1999) describe disintermediation as "the removal of intermediaries in a supply chain, or the cutting out of the middlemen". Carr (2000:46-47) defines reintermediation as "the reformulation, realignment and pruning of intermediaries but without total elimination". However, Sarkar, Butler and Steinfield (2006:2-3) argue that intermediation is a structural feature of the electronic marketplace and its role is not simply taken over by producers. Record labels have re-established themselves in the supply chain through reintermediation.

5 Digital social networking

The emergence of web technologies also enables new forms of interaction between the players in the market such as bandwidth, customisation, and interactivity (Bernardo & Martins, 2013:4). Reach is defined as "connectivity and refers to the number of people involved in exchanging information" (Evans & Wurster, 2000:25). Lam and Tan (2001:63) forecast that as "bandwidth increases and more advanced compression techniques avail themselves, the Internet will become the major distribution channel of music in its digital format". The digital content market is underpinned by social networking and digital technological innovations. Jaakkola, Linna, Henno, Makela and Welzer-Druzovec (2012:252) observe that "social media are media for social interaction, using highly accessible and scalable communication techniques". Web-based and mobile technologies are used in social media to transform communication into interactive dialogue. Chaffey (2015) and Weinberg (2010) state that with the increase in the number of social network sites (SNS), social networking has become a major and focal reason for the music industry to adopt the pull strategy. Chaffey (2015:7) defines social media marketing as "monitoring and facilitating customer-customer interaction and participation throughout the web to encourage positive engagement with a company and its brands. Interactions may occur on a company site, social networks and other third-party sites". Chaffey (2015) and Weinberg (2010) identify the six main types of social presence employed by artists in communicating with fans and vice versa as "Social networking, Social knowledge, Social sharing, Social news, Social streaming and finally, Company user-generated content and community as the company's own social space which may be integrated with product content or customer support". Social media platforms such as Facebook, Instagram, Twitter or LinkedIn have an increasing user base (Chawinga & Zinn, 2016; Gikas & Grant, 2013). However, social networking can have a negative impact on physical and psychological health and cause behavioral disorders (Masthi, Pruthvi & Phaneendra, 2018), depression (Wang, Wang, Wu, Xie, Wang & Zhao, 2018; Tang & Koh, 2017), anxiety and mania (Tang & Koh, 2017).

6 Research methodology

6.1 Research design

The study utilised an exploratory design and a quantitative research approach. Quantitative studies are designed to evaluate objective data and rely on numerical and statistical data. Creswell (2014:4) describes quantitative research as a method used to test theories by examining the relationships among variables. This sampling technique is "based on the judgement of the researcher regarding the characteristics of a representative sample" (Bless, Smith & Kagee, 2006:106). In addition to purposive sampling, snowball sampling offers a quicker and more efficient means to gather data. Babbie and Mouton (2006:167) advise that snowball sampling is appropriate when it is difficult to locate the desired number of members of a special population. A few people from the target population are requested to provide information on how to locate other members of that population whom they know. In this way, they serve as informants and assist in identifying colleagues, acquaintances or friends. The positivist philosophy was adopted to test hypotheses and quantitatively analyse the data, and the deductive approach assisted in testing the theory of diffusion for innovation.

6.2 Target population

In order to compose, produce, record and digitally distribute music, the artist or band needs to reside in an urban area. Urban areas are highly developed and offer efficient access to technology, infrastructure, business development, and professionals in the targeted industry as well as wider audiences. According to Statistics South Africa (2014), KwaZulu-Natal is home to most of the province's population that has access to cellular phones (90.7%); while 24.6% have access to computers, 78.5% to television, 32.4% to satellite television, 71.8% to radio and 32.6% to motor vehicles. The researchers were guided by the theory of Diffusion of Innovation in reaching the targeted musician population in the Durban area. The cornerstone of the research problem rests on force field theory analysis, a change management technique which analyses the forces driving movement toward a digital goal and restraining movement towards the digital ecosystem (hindering forces). As noted earlier, the diffusion of innovation theory posits that in order to diffuse technology or the product, musicians need to reside in areas that have access to the resources required to do so with the support of digital social networks and behavioural dimensions.

6.3 Type of sample and sample size

The RiSA website states that the association has 250 members in KwaZulu-Natal. Although the website does not list members per city, the researchers used deductive logical reasoning together with the theory of Diffusion of Innovation to support the sample size selected. This was achieved by taking into consideration that in order to digitally distribute music, musicians require access to technology-enabling equipment, devices and bandwidth speed. These are available in urban areas such as Durban. A target sample of the respondents was determined from the estimated population of 250 (Sekaran and Bougie 2010:295). However, the final sample was 217, which is almost 87% of the total population. Information was gathered by means of a questionnaire with closed-ended questions. Saunders, Lewis and Thornhill (2012:667) describe closed-ended questions as questions where participants choose responses from a limited number of given alternatives. The three main sections of the questionnaire covered the respondents' biographical variables; dichotomous questions with options of 'Yes' or 'No' answers; and Interval scale or rating questions using a 5-point Likert scaling method ranging from strongly disagree (1), to disagree (2), neutral (3), agree (4) and strongly agree (5). The questionnaires were administered personally and via electronic mail to Durban musicians.

6.4 Data analysis

Data analysis entails the "application of reasoning to understand the data that has been gathered" (Zikmund, Babin, Carr and Griffin 2013:68) and involves "breaking up the data into manageable themes, patterns, trends and relationships" (Babbie and Mouton 2006:104). The data analysis techniques used were in accordance with the study's objectives. The data was captured using the Statistical Package for the Social Sciences (SPSS). In analysing the category of artists with a propensity for entrepreneurialism and an economic dimension rather than romantic individualism, only 27% of the sample belonged to a record label, while 55% of the respondents considered themselves to be independent artists. Social entrepreneurs represented 18% of the population while the remaining 0.9% belonged to the "Other" category, describing the creative nature of their working practice and apathy towards the digital music production cycle. The results show that the advent of the 4th IR has resulted in significantly higher digital music distribution by the artist (70% Myself) rather than by record labels (30% My label). Digital music distribution platforms seamlessly integrate entrepreneurs, individual fans, supply chain partners and sponsors to synthesise co-creation of music services and content for profitable pooling and sharing revenue and experience. Musical entrepreneurs are inherently obliged to seek scalability and flexibility as the result of growth in the scale of digital music and the scope of global reach. South Africa's creative industry, particularly music, must absorb the opposing logics of stability as romantic individualism, and flexibility as a commercial entity and entrepreneurship as a paradox of change. The findings show that the least utilised distribution medium used by musicians is the traditional means (18%), while the most common is electronic distribution (48%); however, 34% of the sample reported that they used both electronic and traditional means of distribution. Furthermore, 28.1% of the sample had less than a year's experience in the music industry, while 45.6% had one to three years' experience, 15.7% had four to six years' experience and 5.1% had seven to ten years' experience. Musicians with more than ten years' experience represented 5.5% of the sample. The analysis of the distribution by music alignment revealed that 53.9% of the respondents created music according to their own artistic taste, while 19.4% responded to label demands and 26.7% to customer demand. Digital social networking and knowledge should enhance the customer or fan's hedonic experience to satisfy demand with the collaborative design of music for an extended consumption cycle. Romantic individualism should afford the confluence of customer demand and the entrepreneurial artist's taste for music alignment.

THE DIGITAL ECOSYSTEM AND ENTREPRENEURIAL MUSIC DISTRIBUTION: A FORCE FIELD PERSPECTIVE

Thokozani Patmond Mbhele; Praveena Ramnandan

Table 1 Party responsible for distribution and medium of distribution

Description	Distribution		Medium of Distribution		
Distribution	Myself	My Label	Electronic Distribution	Traditional Means	Both
	70%	30%	48%	18%	34%
Websites for Music Distribution					
Websites Used to Distribute Music	iTunes	Social Media Sites	SAmp3.com	Napster	Sound Cloud	Other
	19%	52%	17%	5%	22%	7%

In terms of websites used to distribute music, half of the respondents used social media sites (52.1%), while 22% used Soundcloud and 19% used iTunes (Table 1). Surprisingly, SAmp3.com was not the most popular and was cited by only 17% of the respondents. The new Napster, the first website which created disintermediation in the music industry, is at the lower end of the scale (5%). Some of the "Other" categories at 7% mentioned by respondents were YouTube, reverberation, Amazon.com, bandcamp.com, cdbaby, and datafilehost.

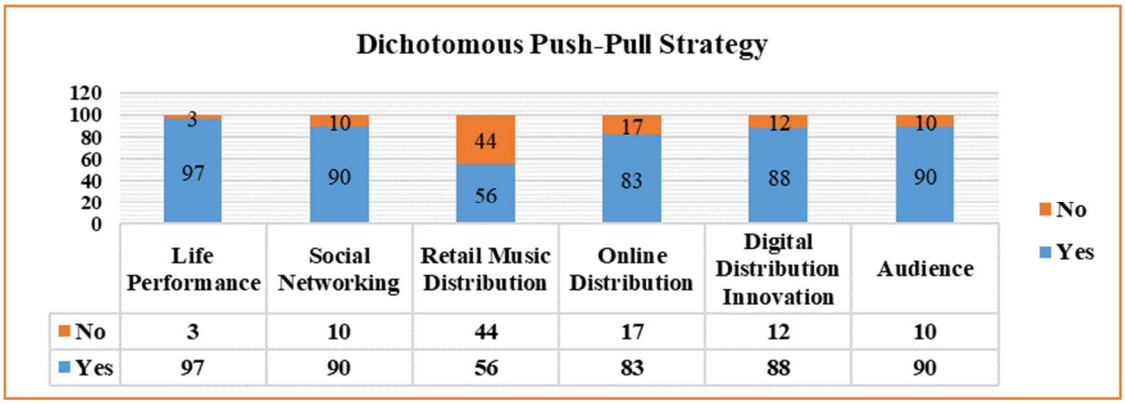


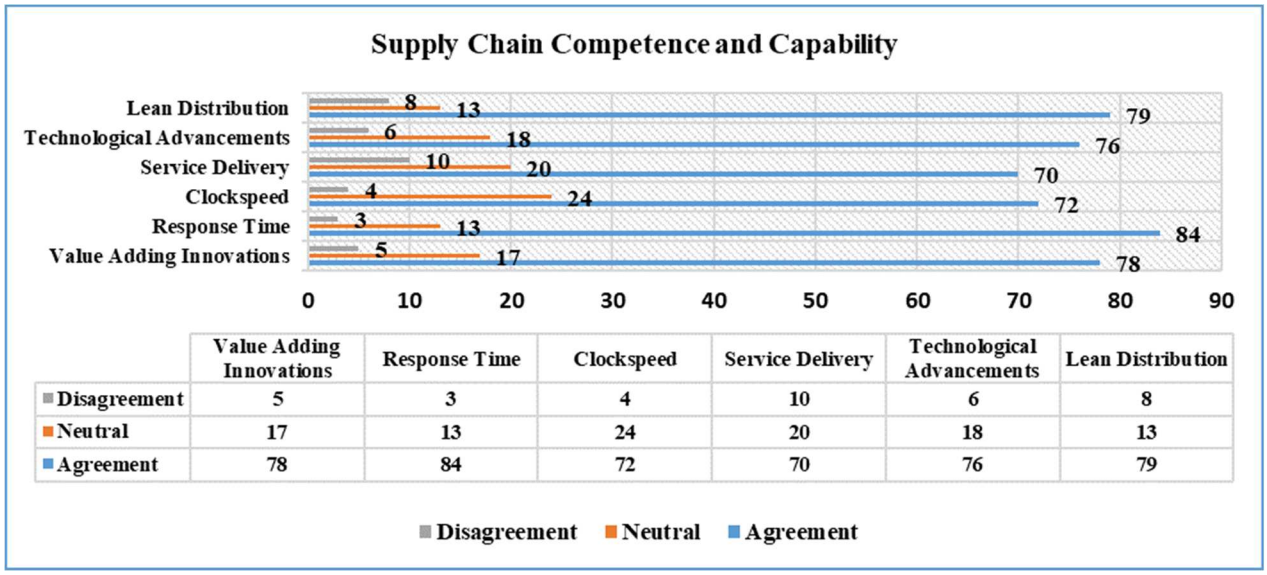
Figure 1 Dichotomous questions relating to Push-Pull strategies

Figure 1 depicts the responses to the dichotomous questions posed to the respondents. The binomial test for the dichotomous questions shows that a significant number of the respondents (97%) indicated that they used live music performances as a promotional activity. Similarly, the overwhelming majority (90%) indicated that social networking mediums increase the market base for music distribution. For non-virtual approaches, 56% of the respondents indicated that retail music stores facilitate easy access to music distribution; however, some (44%) did not agree with the brick and mortar approach to music distribution. Eight-three percent agreed that online music stores facilitate access to music distribution using online social networks. A total of 88% of the respondents agreed that digital music distribution inspires innovation among musicians, while an overwhelming 90% felt that online music attracts a wider audience. Based on the analysis of the push-pull strategies, digitisation of entrepreneurial processes, products and services allows for greater flexibility by separating function from form and content from medium. Digital entrepreneurial innovations push distribution while online social networking pulls geographically dispersed fans and audience in the music industry.

Only 5% of the respondents disagreed that the introduction of innovative products (such as iPads) or services (iTunes), adds value to music, while 78% agreed with this statement. By the same token, 84% of the respondents agreed that music tracks can be re-mixed and uploaded in less time than during the compact disk (CD) era, reducing the response time. An interesting observation is that none of the respondents strongly disagreed (4%) that the digitalisation of music enables a quick response to changing demands, with 72% associating the clockspeed with a swift response, flexibility and agile music distribution. Approximately 70% of the respondents agreed that the Internet is reliable when it comes to the delivery of both music products and services while 20% did not express an opinion. A further 76% agreed that technological advancements have facilitated the evolution of digital music and that the Internet is the most effective way to continuously provide updated or new music offerings to the consumer through lean distribution (79%). Thus, the respondents were in significant agreement on supply chain competence and capability in digital music distribution (Figure 2).

The highest mean value was for the statement that the Internet as a distributor offers lean distribution of updated or new music offerings to consumers (m=4.11 and standard deviation=0.98). Value adding innovations (such as iPods) or services (iTunes) add value to music (m=4.09 and standard deviation=0.96). Re-mixing music tracks can be

achieved in a shorter time than during the traditional CD era (m=4.2 and standard deviation=0.79). In addition to supply chain competence and capability, technological advancements have facilitated the evolution of digital music (m=4 and standard deviation=0.85). The supply chain's competence and capability in terms of service delivery has the lowest mean value of 3.86 and standard deviation=0.97, indicating that the respondents agreed that the Internet is reliable in the delivery of both music products and services. Table 2 indicates that the majority of respondents agreed that clockspeed music delivery exists in the supply chain, while a mean value of 3.95 and standard deviation=0.79 illustrate that the respondents agreed that the digitalisation of music enables a quick/swift response to changing demands.



	Value Adding Innovations	Response Time	Clockspeed	Service Delivery	Technological Advancements	Lean Distribution
Disagreement	5	3	4	10	6	8
Neutral	17	13	24	20	18	13
Agreement	78	84	72	70	76	79

Figure 2 Likert scale analysis - supply chain competence and capability

Table 2 Descriptive statistics on supply chain competence and capability

	Lean distribution	Value adding innovations	Response time	Technological advancements	Clockspeed	Service Delivery
N	217	217	217	217	217	217
Mean	4.11	4.09	4.2	4	3.95	3.86
Median	4	4	4	4	4	4
Mode	5	5	4	4	4	4
Std. Deviation	0.975	0.958	0.791	0.853	0.806	0.967

In terms of Pearson Correlation: Supply Chain Competence and Capability, there is a strong positive correlation between the constant variable value adding innovations and response time (r=.165 and p=0.015); clockspeed (r=.204 and p=0.003); the Internet as a reliable means for the delivery of music products and services (r=.254 and p=0); and technological advancements (r=.159 and p=0.019). These variables illustrate a key idea behind digital distribution. Response time, clockspeed delivery, service delivery and technological advancements not only complement each other, but one another and combine to create a competent and capable supply chain. This in turn creates supply chain competitiveness. Despite these positive findings, there is a statistically significant strong negative correlation between innovations adding value to music and the Internet as a medium of lean distribution (r=-0.016 and p=0.816). A correlation matrix was used to predict the relationship between all possible pairs of variables using significance level of p = 0.05. The significance level shows how possible it is that the correlations reported may be due to chance in the random sampling error. A correlation matrix provides details of acceptable positive correlation values between each pair of variables with significance of less than 0.005.

6.5 Factor analysis

Cronbach's Alpha value indicates the level of internal consistency by showing construct validity where the constructs are measured with sufficient reliability. Assessing the variables on the 5-point Likert scale, the Cronbach's Alpha of the instrument is 0.826. The reliability of each dimension relating to digital music

distribution was also assessed, and the dimensions have strong to very high levels of reliability. According to Cooper and Schindler (2010), "acceptable alpha values range from 0.7 to 0.95". Therefore, the researchers infer that the instrument is reliable. Factor analysis reduces items to manageable factors. The adequacy of the sample was further determined using the Kasier-Meyer-Olkin (KMO) Measure of Sampling Adequacy.

Table 3 Rotated component matrix

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.812
Bartlett's Test of Spherecity	Approx. Chi-square	1030
	Df	231
	Sif.	0.000

Rotated Component Matrix

	Factor Loading	**Eigenvalue**	**% of Variance**	**Cumulative %**	**Communalities Extraction**	**Alpha**
Factor 1: Digital Responsiveness						
Service delivery	0.742	1.824	8.293	30.747	0.479	0.577
Clockspeed	0.605				0.469	0.568
Factor 2: Digital Alliance						
Value adding innovations	0.73	1.105	5.023	48.91	0.61	0.644
Digital distribution value	0.727				0.647	0.625
Extraction Method: Principal Component Analysis.						
Rotation Method: Varimax with Kaiser Normalization.						
a. Rotation converged in iterations.						

The KMO score of 0.812 > 0.6 indicates sampling adequacy as a desirable value with a suitable level of variance. The Bartlett's Test of Sphericity (1030.375) was used to verify the assumption of homogeneity of variance. The Bartlett's Test gave a significant p-value of 0.000 at the 95% confidence level for factor analysis to be deemed appropriate. The significance of the Bartlett's test confirms that there is some level of correlation among the variables (Pallant, 2011:323-326). The data matrix therefore had sufficient correlation for the application of factor analysis. The score of 0.812 presented by KMO depicts the strength of the other variables in explaining the correlation between potential factors. In factor analysis, the KMO (0.812) and Bartlett's test of sphericity (1030.375) scores are suitable at degree of freedom (231) (Garson, 2012; Hatcher, 1994). Communality refers to the amount of variance that can be explained by the common factors of a variable (Pallant, 2011; Saunders, Lewis & Thornhill, 2012). Communality values range from 0 to 1, where 0 indicates that the common factors do not explain any variance and 1 means that they explain all the variance (Pallant, 2011; Saunders, Lewis & Thornhill, 2012). In general, values of less than 0.3 indicate that the item does not fit well with the other items in its component. Table 3 shows that all the items have an extraction value greater than 3; they thus fit well with the other items in their component. The factor extraction procedure determines the intention of reducing the complexity of the factors by stating the factor loading in a clearer, more understandable and interpretable manner (Costello & Osbourne, 2005; Hatcher, 1994). According to Hatcher (1994:21) "principle components analysis converts a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. The number of principal components is less than or equal to the number of original variables". Garson (2012) notes that the loadings of Likert scales with 0.6 may be considered "high". An alternate way to perform factor extraction is to use Kaiser's criterion or the eigenvalues rule. Using the eigenvalues rule, only factors with a value of greater than 1.0 are retained for further investigation. By rule of thumb, any factor that has an eigenvalue of less than 1.0 does not have enough total explained variance to represent a unique factor, and is therefore disregarded (Pallant, 2011; Saunders, Lewis & Thornhill, 2012). In this analysis, components 1, 2, 3, 4, 5 and 6 have eigenvalues greater than 1 and relate to 4.94, 1.824, 1.664, 1.227, 1.105 and 1.072, respectively.

Factor 1: Digital Responsiveness - indicates that two items load significantly on Factor 1 and account for 8.293% of the total variance. The two items relate to

service delivery and clockspeed, both of which enhance flexibility in the supply chain through agility. Digitalisation of music enables swift responses to changing demands in the market. Furthermore, the Internet seems reliable in the delivery of both music services and products in entrenching supply chain distribution competence and capability. An agile supply chain system reflects a certain level of flexibility that creates considerable resilience in responding to the disintermediation of the retail music industry. The digital environment facilitates more exposure by broadening musicians' audience base, eliminating the influence of gatekeepers, and facilitating omni-supply chain distribution through discretional social networks.

Factor 2: demonstrates two variable loadings which account for 5.023% of the total variance. The two factors are value-adding innovations and digital distribution value. They are thus, interpreted and labelled as "Digital Alliance". The relationship between the digital distribution of music adding value in the growth of the South African recording industry and the introduction of innovative products such as iPods or services (iTunes) adding value to music equates at the level where complementary technologies and devices encourage music consumption and distribution.

7 Discussion of results

As device convergence, digital music devices facilitate communication with fans, storage of online music and nimble production of music tracks by processing information and offering information services as network convergence. The music industry / market convergence through digitised global reach and repositioned social media facilitates the entrepreneurial music process of convergence. The article reflects on the commingled triadic theme of the entrepreneurialism model, romantic individualism as the creative sector and digital music generativism as digital convergence of organic growth and profitability. Technology has the ability to bring flexibility while people have natural ability, enabling responsiveness, agility and empowered accountability which enhance the customer service experience. Digital social networks employ the term imbrication as a way of specifying an interaction that is not characterised by hybridity or blurring, but social digital networks with global span to reach diversified fans.

The study's first objective was to examine digital entrepreneurship's influence on the dynamic social networking market with the infusion of disruptive and innovative technology (a push-pull strategic approach). In analysing the category of artists with a propensity for entrepreneurialism and the economic dimension rather than romantic individualism, only 55% of the respondents considered themselves to be independent artists. Social entrepreneurship (18%) describes the creative nature of their working practice and apathy towards digital music production. The advent of the 4th IR has resulted in a significant increase in digital music distribution by the artist (70% Myself) rather than distribution by record labels (30% My label). Digital music distribution platforms seamlessly integrate entrepreneurs, individual fans, supply chain partners and sponsors to synthesise co-creation of music services and content for profitable pooling and sharing revenue and experience. The analysis of distribution by music alignment revealed that 53.9% of the respondents created music according to their own artistic taste, while 19.4% responded to label demands and 26.7% to customer demand. Digital social networking and knowledge should enhance customers or fans' hedonic experience to satisfy demand through the collaborative design of music for an extended consumption cycle. Romantic individualism should afford the confluence of customer demands and entrepreneurial artists' tastes for music alignment. In terms of websites used to distribute music, half the respondents used social media sites (52.1%), while 22% used Soundcloud and 19% used iTunes with 17% on SAmp3.com. Social network sites include popular social media sites Facebook, Twitter, Google+, and Myspace; while social media marketing includes online video and interactive applications featured on special social network sites such as YouTube.

Artists are using live music performances as a promotional activity, and social networking mediums seem to increase the market base for music distribution (90%). For non-virtual approaches, retail music stores as brick and mortar (56%) facilitate easy access to music distribution. Online music stores better facilitate access to music distribution (83%) with reliance on online social networks. Digital entrepreneurship (88%) enables digital music distribution, which inspires innovation among musicians while the availability of online music (90%) attracts a wider audience. Based on the analysis of push-pull strategies, digitisation of entrepreneurial processes, products and services allows for greater flexibility by separating function from form and content from medium. Digital entrepreneurial innovation pushes distribution while online social networking pulls geographically dispersed fans and audiences. The ability of service providers and peer-sharing websites to compete through a combination of marketing and operational functions creates competitive advantage by providing what the customer demands. In the music industry, the pull effect is the result of consumer demand for digital music content, and the quicker the service provider obtains and provides the digital content wanted by customers, the more likely it is that they will retain them.

The second objective focused on entrepreneurship capability and competence that impact on digital music change management. The introduction of innovative products (78%) (such as iPads) or services (iTunes), adds value to music for capable economic dimension and competitive business enterprises. Music tracks can be re-mixed and uploaded in less time (84%) than during the compact disk (CD) era, reducing the response time. Extant

business and management literature on digital entrepreneurship suggests that economies of scale and electronic creation of value are expected benefits of entrepreneurship. Organisations that create value with digital assets are likely to obtain income through an infinite number of transactions because a song is recorded once, but in its digital medium it can be duplicated or replicated and distributed an infinite number of times at a low cost (Fox, 2004:204). On the other hand, a song recorded once and sold a multitude of times results in increased profits for e-tailers or the artist. These operational processes are interrelated and provide retailers with the tools they need to be competitive in the marketplace. An interesting observation is that the digitalisation of music enables a quick response to changing demands, with 72% of the respondents associating the clockspeed with a swift response, flexibility and agile music distribution. Seventy percent of the respondents agreed that the Internet is reliable when it comes to delivery of both music products and services. The digital ecosystem can be applied in business, knowledge management, services, social networks, and education. Evolving sociotechnical systems require diverse information technology capabilities that are deeply socially embedded to enable new social behaviours and regulatory reforms. Seventy-six percent of the respondents agreed that technological advancements have facilitated the evolution of digital music and that the Internet is the most effective way to continuously provide updated or new music offerings to the consumer using lean distribution (79%), and supply chain competence and capability in digital music distribution. Response time, clockspeed delivery, service delivery and technological advancements complement one another and combine to create a competent and capable supply chain.

The third objective was to examine the extent to which digital music distribution balances the driving forces of digitisation and the restraining forces from disruptive technology. The interrelationship between the variables produced the Digital Responsiveness factor on digital entrepreneurship relating to service delivery and clockspeed, both of which enhance flexibility in the supply chain through agility. Digitalisation of music enables swift responses to changing demands in the market. Furthermore, the Internet seems reliable in the delivery of both music services and products in entrenching supply chain distribution competence and capability. An agile supply chain system reflects a certain level of flexibility that creates considerable resilience in responding to the disintermediation of the retail music industry. The digital environment facilitates more exposure by broadening musicians' audience base, eliminating the influence of gatekeepers, and facilitating omni-supply chain distribution through discretional social networks. The second factor known as the Digital Alliance examined the relationship between the digital distribution of music adding value in the growth of the South African recording industry and the introduction of innovative products (such as iPods) or services (iTunes) adding value to music. It equates to the level where complementary technologies and devices encourage music consumption and distribution.

8 Reliability and validity

The reliability of a research instrument is determined using the method of internal consistency. The respondents were asked to rate variables on a 5-point Likert scale where 1 indicated 'strongly disagree' and 5 'strongly agree'. Cronbach's Alpha was used to test the reliability of the instrument and also depicts the internal consistency of the study. The Cronbach's Coefficient Alpha value (0.826) indicates the level of internal consistency by showing construct validity where the constructs are measured with sufficient reliability. Internal consistency is discussed in terms of the interrelatedness among the items in the study. However, interrelatedness of items does not indicate unidimensionality and homogeneity. The reliability statistics generated from the SPSS indicate that the instrument has a moderate level of internal consistency for reliability as suggested by the Cronbach's Alpha. Furthermore, the questionnaire had a high level of inter-item consistency (Cronbach's Alpha = 0.826), implying that it has a high level of reliability. Therefore, the researchers infer that the instrument is reliable in relation to the dimensions of digital music distribution. The reliability of each dimension relating to digital music distribution was also assessed. The dimensions of digital music distribution have strong to very high levels of reliability. Validity is "the degree to which evidence and theory support the interpretations of test scores entailed by the proposed uses" (Fritsch, 2016:14). Content validity is therefore a function of how well the elements and dimensions of a concept have been explained (Sekaran & Bougie, 2011:159). Construct validity has to do with the results obtained from measuring the theory from which the test is designed. It occurs when the researchers use adequate definitions and measures of variables (Creswell & Creswell, 2018:160). Construct validity tests a scale "in terms of the theoretically derived hypotheses concerning the nature of the underlying variable" (Pallant, 2010:7). It considers the degree to which a research tool is able to measure the construct it intended to measure. Homogeneity, convergence and theory evidence are used to demonstrate construct validity (Taherdoost, 2016:28). Content validity is defined as the adequacy with which a measure or scale has sampled from the intended domain of content provided in this article (Pallant, 2010:6).

9 Conclusion and suggestions for further research

The Internet seems reliable in the delivery of both music services and products in entrenching supply chain distribution competence and capability. Artists with a propensity for entrepreneurialism and economic dimension

rather than romantic individualism consider themselves to be independent artists. The disintermediation of record labels, reintermediation of digitised labels and social network sites, and the introduction of innovative products (such as iPads) or services (iTunes) adds value to music for capable economic dimension and competitive business enterprises. It is essential for music alignment to create music according to their own artistic tastes and customer demand. Musical entrepreneurs are obligated to adopt scalability and flexibility as a result of the growth in the scale of digital music and the scope of global reach. The South African creative industry, particularly music, should absorb the opposing logics of stability as romantic individualism and flexibility as a commercial entity and entrepreneurship as a paradox of change. The study shows that digital music production, distribution and consumption have been adopted by a considerable percentage of musicians. Further research could investigate regulatory improvement and compliance while developing a viable system to curb the dilemma of copyright.

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HAND 3D SCANNING POSSIBILITIES

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Keywords: 3D scanning, hand, forearm, grip, grasping
Abstract: 3D scanning as an innovative method of obtaining specific substrates for the design of prosthetic-orthotic devices is now becoming increasingly popular. The advantages of this technology over the classic way of taking the dimensional and shape characteristics of parts of the human body are its non-invasiveness, speed, archiving and, more recently, the possibility of using a low-cost 3D scanner, thus reducing economic demands and making the technology available to most orthopaedic technicians. The article offers a comprehensive overview of the correct positioning of the hand and fingers for selected types of gripping as well as possible complications in their scanning, for the achievement of correct digital models applicable to the design of personalized orthotic devices.

1 Introduction

Today, technological developments offer several possibilities for obtaining detailed information about the internal structure of objects. Digitising the outer shape of real objects becomes a standard tool in various sectors e.g., engineering, quality management, forensic sciences, archaeology and medicine, especially in the field of prosthetics and orthotics. For these purposes, 3D scanners, devices that convert a real object into a digital form, capture information about the shape, dimensions and texture of real objects, and then transform them into a digital form for further computer processing [1].

2 Hand and its basic functions

In the process of human development, the hand played one of the key tasks. The interaction of the hand as an organ that enables work, and work as an activity that forms and improves the hand, has a decisive impact on the development of the relevant areas of the brain, thereby on the development of man as an animal species with an exceptional position in nature. The human hand is distinguished from other animals by creating the ability of the thumb opposition, i.e., converting the hand from the movement organ (used in walking) to the gripping organ. The main function of the hand is to grasp the object and press it with such force that the hand can move the object.

The hand with the wrist, as its functional part, consists of 27 bones, has over 20 joints and 33 different muscles and nerves participating in controlling its movement. The human hand is a highly mobile organ that allows combination of several movements [1].

The bones of the hand are arranged into three arches, which are reinforced by the inner muscles of the hand. Those are two transverse arches and one longitude arch.

Most of the activities are done between the thumb and forefinger or middle finger, the remaining two ring fingers and the little finger serve as auxiliary fingers.

The grip can be generally defined as active handling of an object with a purpose of holding it and using it for an activity. For an optimally performed grip not only hand and the entire upper limb must take the right position, but also the body and its individual functional segments. From the typology point of view, grasping can be divided into 2 main groups, on precise (fine) grasping and power (force) grasping [1][2].

For precise grasping, the object is located between the tips of the fingers and thumb, while the thumb is in the abduction. These grips provide precise and gentle movement with objects that are small and fragile, and can be divided into lateral, terminal and opposition grips [3]. The power grasping is used when the object needs to be held by force. Fingers tend to bend in one direction and the thumb embraces the object. Power grasping is further divided into cylindrical, spherical, hook and directional grip.

3 Hand 3D scanning

Before the scanning of upper extremities, it is advisable to know the purpose for which the digitization of the segment is carried out. If the model of the limb is to serve as a blueprint for designing of an orthopaedic device, it is necessary to consider the functional purpose of the device. Should the function be dynamic or static? If the segment needs to be fixed, it is advisable to perform a scan in the position in which the segment should be fixed. The scanning position also depends on the quality of priority areas [3].

When digitising the entire upper limb, it is optimal to capture the subject in a sitting position with the upper limb abducted (120° to 160°), ensuring an appropriate scanning distance and relatively free access from all sides. In this position, however, it is necessary to know that the subject may not maintain a sufficiently static position, and in the distal part of the limb, movement may occur, which may not be compensated when processing the digital model. This creates a risk of reduced accuracy of the resulting model, its morphological deformation as well as the formation of artefacts and bifurcated scans due to the impossibility of correct alignment (Figure 1).

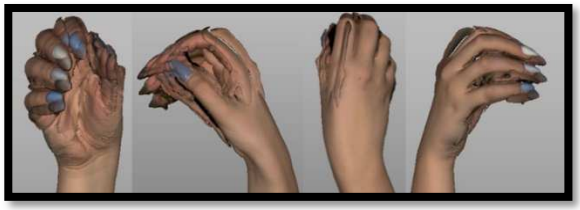

Figure 1 Example of a bifurcated model

When scanning the area of the hand and forearm, it is advisable to stabilize the elbow joint by resting it against the mat, thus significantly facilitating the ability to keep the distal segment in a stabile position. The position of the thumb and fingers must be chosen according to the purpose to which the model will serve. The thumb may be positioned in opposition if the resulting position of the model of the hand is to be rested or active, or in a reposition if the aim is to focus on the entire palm area. Fingers can be digitized in mutual adduction or abduction.

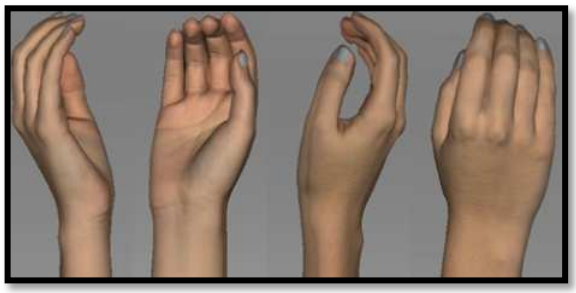

Figure 2 Scan of the hand area with the fingers in a mutual adduction

When scanning with the fingers in adduction, it is not possible to capture the gap between the fingers, so it is necessary to count on the fact that the second to the fifth finger will be captured as a single unit (Figure 2). However, digitisation itself is simple and there is no need to focus on scanning the lateral aspects of individual fingers.

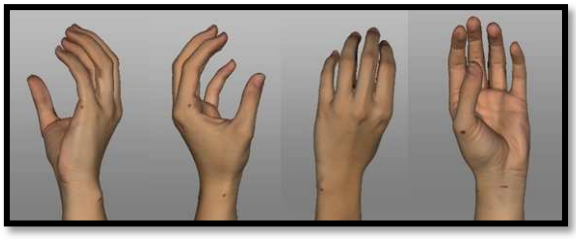

Figure 3 Scan of the hand area with the fingers in a mutual abduction

When digitising the hand with abducted fingers, it is essential to adjust the gap between each finger, so that it can capture their lateral aspects well (Figure 3). If the gaps are too wide, the natural position of the hand is lost and passes into the form of a spherical grip, if the gaps are too narrow, it is difficult to obtain a model with separate fingers without deformations and artefacts.

When digitizing the fingers, it is necessary to pay attention to the area of distal digits and scan the entire area of the edge of the nail, especially from the palmar side. The area of distal digits is critical in the formation of the model in terms of the risk of deformities and artefacts (Figure 4).

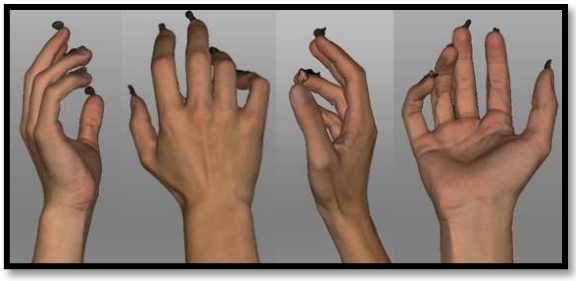

Figure 4 Artefacts on the distal finger digits

3.1 Grasp scanning

The following four grips - spherical, cylindrical, lateral and opposition grip - are selected to showcase the options within the grasp scanning.

3.1.1 Spherical grip

The distal (DIP) and proximal interphalangeal (PIP) joints are approximately in 30-degree flexion and the thumb is abducted relative to the metacarpophalangeal (MCP) joint. Forces are formed between the fingers and the palm.

Figure 5 Scan and photography of a spherical grip

The spherical grip is relatively simple from a scanning perspective (Figure 5). Since the fingers are in mutual abduction, it is possible to take a good scan of their lateral aspects. If the wrist is positioned between 45° palmar to 60° dorsal flexion, the dorsal aspect of the hand is very well digitized. It is necessary to focus on the distal parts of the fingers and when scanning with a holding object on the transition between the object and fingers, where the transition between the texture of the object and the hand doesn't have to be clearly defined (Figure 6).

Figure 6 Scan and photography of a spherical grip with an object

A well-captured texture of both the hand and the held object – the apple (Figure 7) is visible on the scan. The fingers are clearly separated, also the aspect of the palm is taken. Distal digits that are free of artefacts are also digitised.

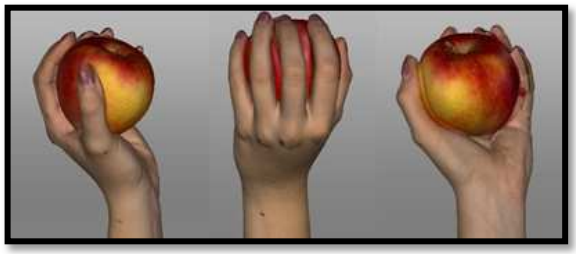

Figure 7 Example of a spherical grip with an object

3.1.2 Cylindrical grip

With the cylindrical grip, fingers and thumb are in flexion and the thumb embraces the object in the opposite direction to the fingers. Scanning the cylindrical grip without the object is quite difficult. This grip can be scanned with the second to the fifth finger with mutual abduction (Figure 8). In the first case, it is not possible to capture the gap between the fingers and therefore it is necessary to know that the fingers will be captured as a single unit. However, it is possible to modify and separate them. When scanning the cylindrical grip without the object, it is difficult to capture the ventral surfaces of the fingers, as they are strongly oriented towards the palm. It is therefore appropriate to be aware of reduced scan accuracy and possible occurrence of artefacts in this area and thus the need for a higher degree of additional modification and modification of the model.

Figure 8 Scan of a cylindrical grip without an object with adducted and abducted fingers

In the case of scanning the cylindrical grip with separate fingers, it is necessary to appropriately create a gap between each finger in order to maintain the grip, while at the same time make it possible to capture the lateral aspects of each finger with enough precision. In this case, it is often to redo the positioning and recapture the grip. Making a suitable scan of the cylindrical grip without the object requires experience in finger and hand positioning as well as in scanning.

While the most difficult part is to capture the palmar aspect of fingers, when grasping the object, this problem is

eliminated. It is necessary to focus on setting the appropriate gaps between each finger (Figure 9).

Figure 9 Cylindrical grip with an object

3.1.3 Opposition grip

It represents a press between the volar side of the pulp of the last digits of most of the first three fingers, i.e., three-point (but it can also be four points). It is mainly used when holding stationery.

Scanning an opposition grip without an object is relatively easy, but if a scan with a grasped object is required, the process is complicated. The quality of the resulting model depends heavily on the position of the fingers, which do not participate in the grasping. It is best if they are extended in MCP, proximal and distal interphalangeal joints in mild flexion, thus allowing for the scanning of the palmar area.

Figure 10 Opposition grip without an object

On the scan of the opposition grip without the object, the arches of the hand are clearly visible, as well as the articulated areas of the fingers, creases and palm drawing (Figure 10).

Figure 11 Opposition grip with an object - whiteboard marker

As can be seen in the images of the opposition grip with the object (whiteboard marker), the quality of the resulting scan is excellent, as the requirement for extension fourth and fifth finger in the MCP joint has been met and thus the digitization of the palm as well as the palm aspects of the fingers has been allowed (Figure 11).

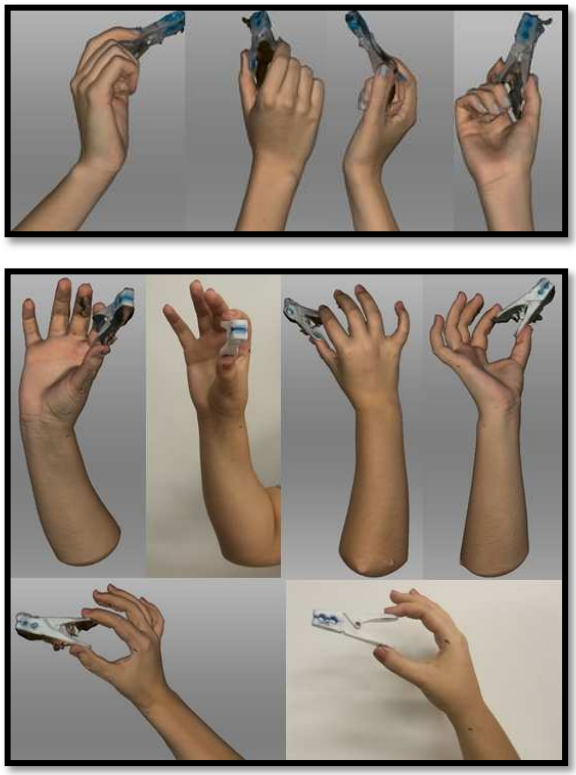

Figure 12 Opposition grasping with flexed and extended fingers

The figure shows an example of a scan with flexed fingers and the subsequent creation of artefacts in the area of the handled object, thumb and distal digit of the second finger (Figure 12). Represented below is a scan of the same subject with extended fingers and therefore enough space for data collection.

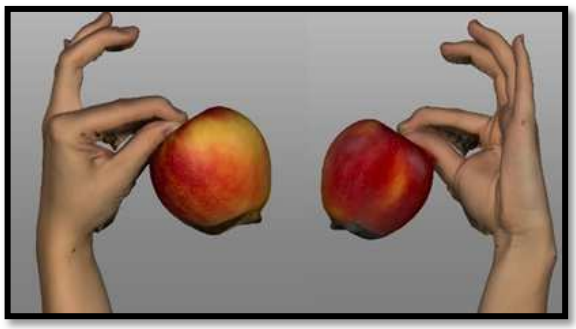

Figure 13 Artefacts between the second finger and the thumb

The picture below presents an insufficient scan of the palmar aspect of the thumb and the second finger, therefore, there is no clearly defined surface and gap between these aspects (Figure 13). The artefact is created when the model is processed and edited to fill in the missing data. It can be deleted by changing the crack fill setting or by modifying the created model.

Figure 14 Example of an unsuitable positioning during scanning

The figure shows an example of inappropriate positioning when scanning. The dorsal part of the hand and fingers as their distal aspect are very well accessible. However, the held object (an apple) prevents the capturing of the palmar aspect, where the non-compliant morphology and texture of the hand as well as the apple itself is subsequently created (Figure 14).

3.1.4 Lateral grip

With this grasp, considerable force can be exerted, and the tool coordinated. The thumb is in adduction on the radial aspect of the second fingers second digit. This grip is important for the coordinated handling of small objects.

Scanning the lateral grip, whether with or without the object, is quite easy. The resulting scans are of good quality, mostly without obvious deformations or artefacts. Second to fifth finger may be flexed in both MCP, PIP and DIP joints (in which case it is important to pay close attention when scanning the contact of distal digits and the palm) (Figure 15) or with flexed MCP and PIP joints and extended DIP joints (Figure 16).

Figure 15 Visible deformity of distal digits with flexed DIP joints

Figure 16 Satisfactory scan of the lateral grip without an object

Scanning of the lateral grasp with an object is not complicated, however, proper positioning is required, so that the object is accessible for scanning from all sides (Figure 18).

Figure 17 Lateral grip with an object

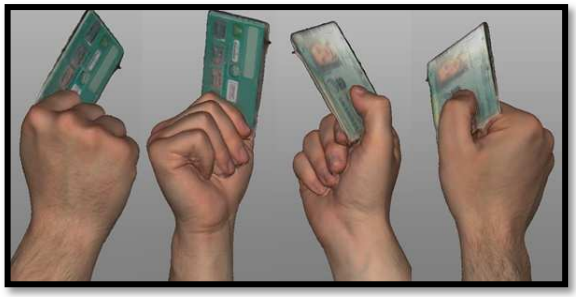

Figure 18 Example of a correct hand and object positioning during lateral grasping

4 Conclusions

3D scanners currently have a major impact on both medical research and practice, and their use for the purpose of obtaining the shape and dimensional parameters of the human body is very beneficial.

Digitising the hand in selected resting, functional, or gripping positions with a selected object or in its pathological position is currently advantageous in CAD designing of personalised orthotic devices in terms of their function as well as the offering of countless alternative options for model modifications.

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REDUCTION OF POLLUTANTS IN THE RESIDENTIAL SECTOR BY MIXING HYDROGEN INTO THE NATURAL GAS NETWORK IN HUNGARY

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Keywords: hydrogen in natural gas system, renewable energy comsumption, GHG reduction, hydrogen-natural gas mixture
Abstract: According to some forecasts, hydrogen will play a significant role throughout the world by 2030 as an energy source, the biggest benefits of which include not only being able to come from renewable sources, but thus storing the energy produced, which is not currently solved. The combustion of hydrogen does not produce CO_2, only negligible amounts of combustion air, unlike methane. This will reduce GHG emissions associated with end-user equipment. In this article, the authors examine the amount of hydrogen that can be fed into the Hungarian natural gas network in accordance with the current gas quality standard, and then carry out a comparative analysis of the methane, the main component that makes up hydrogen and natural gas. The authors will study the exact effect of hydrogen content on natural gas-regulated devices and estimate the theoretical CO_2 emissions available in the Hungarian residential sector at different rates of hydrogen.

1 Introduction

One of the most pressing global challenges of our time is to stop climate change. A significant group of impact gases emitted into the atmosphere can be linked to energy use and, as a means, to end-user combustion plants. At European level, the desire to increasingly replace conventional fossil fuels with renewable sources is growing, from industrial-scale electricity generation to the communal and residential sectors.

The highest GHG emissions from gas-fuelling gas-based wastes come from the carbon dioxide generated by the combustion. Renewable gases to be introduced into the gas grid are the most promising substitutes for natural gas, hydrogen being a legitimate priority on the part of the government, but it is necessary to examine exactly what impact this has on the devices regulated for natural gas.

In the European Union, we hear about a number of projects that aim to examine the issue, but there are no concrete results that can be introduced into domestic practice yet [1]. Based on the results of most research, about 15-20% hydrogen can be fed into the natural gas network without any or very small modification of gas user equipment. Even this amount of hydrogen is resulting in a significant reduction in GHG emissions. The authors set out to estimate the theoretical emissions of pollutants available in the residential sector in Hungary at different levels of gas network hydrogen mixing ratios.

One of the largest user segments of the natural gas sector is the residential sector in the EU and also in Hungary. In 2018, this sector supplied 3.35 billion m^3 of natural gas to the 3.26 million Hungarian residential customers in Hungary [2]. The numbers show the weight of the problem, as gas-supplying appliances in the residential sector are very large and cannot be switched, or only with significant economic investment, to fire up other gas quality. The question is therefore what is still permissible gas quality that can be fired with sufficient energy efficiency and safety in natural gas-controlled appliances.

2 Requirements for mixed hydrogen into natural gas system

Current European research [3,4] foresees that a maximum of 10% and possibly 20% is expected to be the rate that can still be safely mixed with the current gas equipment stock.

On the basis of the literature analysis, the following findings can be made for the retail sector:

- The residential sector has a large number of devices with an in homogenic distribution, type, age and technical condition.
- Most domestic and municipal gas-supplying appliances are likely to be able to handle the natural gas-hydrogen gas mixture without problems with a minimum (5-10%) in the case of an implication rate.
- The behaviour of atmospheric air pre-mixing and ventilation burners shall be tested separately.
- It can be concluded that the risk of natural gas consumption appliances with a hydrogen content of 10% depends essentially on two factors: the primary air volume and the Wobbe number of natural gas.
- The most sensitive to changes in hydrogen content are atmospheric burners.

REDUCTION OF POLLUTANTS IN THE RESIDENTIAL SECTOR BY MIXING HYDROGEN INTO THE NATURAL GAS NETWORK IN HUNGARY

István Szunyog; Anna Bella Galyas

- On the basis of the international test results so far, no general determination can be made on the maximum permissible hydrogen content!

The problem should essentially be examined from two perspectives, from the side of the device technique and the quality of the mains gas.

The technical side of the apparatus is the gas appliance tests carried out by certification and certification bodies on the basis of the test standards set before the gas appliances were placed on the market in that country. The gaseous apparatus tests shall be based on the principle that the operation of the apparatus shall be tested with reference gas of a specified quality and the associated boundary gases and test pressures indicating extreme gas quality. If the operation of the appliance with these gases is satisfactory, it may be placed on the market in the country of destination by actuating the gas of that group of gases. It should be mentioned here that this makes the issue more complex, since consumers also have devices that were put in place 20 or 30 years ago, and often we do not know their frequency of maintenance. So, the risk is a given. The increasing hydrogen share also means an increasing flame propagation rate, gradually increasing the risk of flame re-ignition into the burner. Unfortunately, there may also be old appliances for consumers that do not have or do not have a flame-protection, flame-guard unit.

Figure 1 shows the flame propagation rate values for a pure gas composed of methane, a gas of 70% methane and 30% hydrogen, and a gas with a hydrogen composition of 50% and 50%. It can be seen that the maximum values are around 10% excess air i.e., here the most ideal mixture of gas and air is in terms of combustion processes. It is a good thing that the maximum flame propagation rate that is developing is around 40 cm/s for methane, but for a 50-50% mixture, this is already 1.6 times that which the burner of the device can no longer tolerate and the flame can ignite. It can be concluded that testing the flame propagation rate is an essential requirement [5].

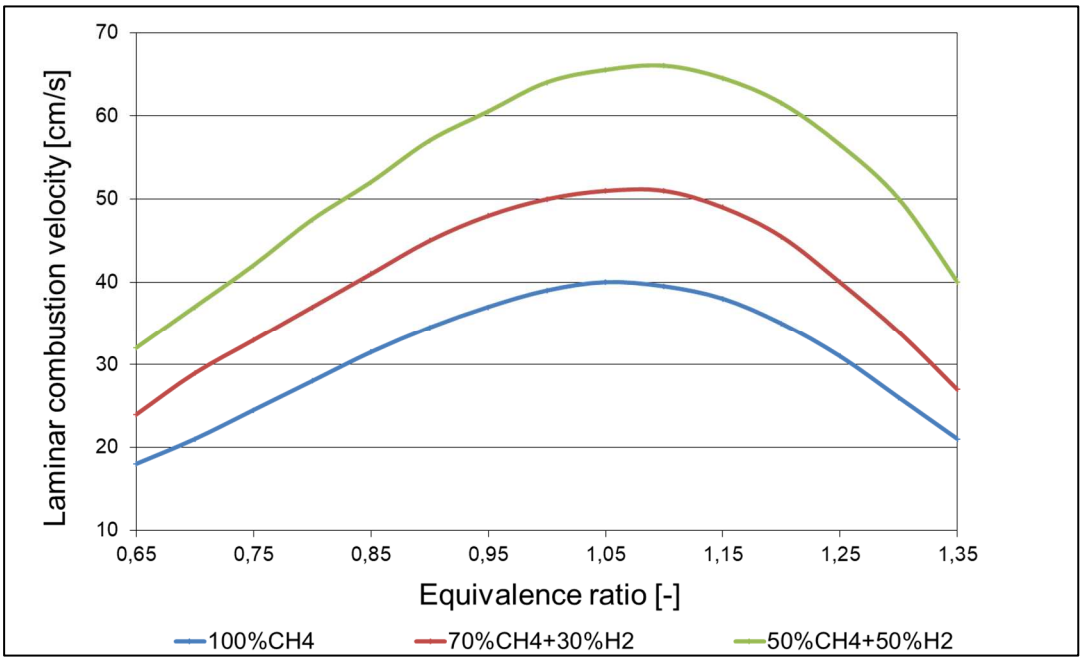

Figure 1 Laminar combustion velocity of methane-hydrogen gas mixture

On the gas quality standards side, the question can be concluded that keeping the quality of gas supplied through the natural gas network within narrow limits is in the fundamental interest of system operators. Disturbing changes in gas quality would put into question the safe and energy-efficient operation of end-user equipment. When regulating the feed of combustible gases of a quality other than natural gas into the natural gas system, the quality parameters of the gas supplied should remain at the heart of the set of requirements. The standards and specifications most used in Europe are based on EN 437 i.e., compliance with Wobbe number [6]. The standard follows the principle that only a change in the burning characteristics of natural gas within a group of natural gas may be allowed which does not affect the operation of the gas appliances and does not require the conversion of the appliance or burner. Gas other than natural gas belonging to the original quality group may only be used after the proper adjustment of the appliance (component replacement, reassembly, adjustment). In the case of the H gas group, which is also crucially available in Hungary, the standard has provided for a test with a hydrogen content of 23% in the border gas of re-ignition since 1999, but this does not provide a close guarantee that the devices installed thereafter would be able to wither this effect continuously and over the long term.

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If a pure methane-hydrogen gas mixture is used, a hydrogen content of not more than 25,45 mol% is allowed in the mixture, so that the mixture still meets the heat value for gas group H, and 41,09% hydrogen may still meet the requirements of the Wobbe number i.e., it may remain within the permitted ranges for the gas group. (Figure 2) It follows that, for an average natural gas composition, the maximum proportion of hydrogen that can be fed into the gas group H is approximately 25% i.e., there is no group change. This is confirmed by the maximum share of 20 mol% and 23 mol% respectively of the limit gases in EN 437. We note that this theoretical number is only approximated from the gas quality side, it does not provide information about the operating side of the device, its behaviour (in particular the changing flame propagation rate).

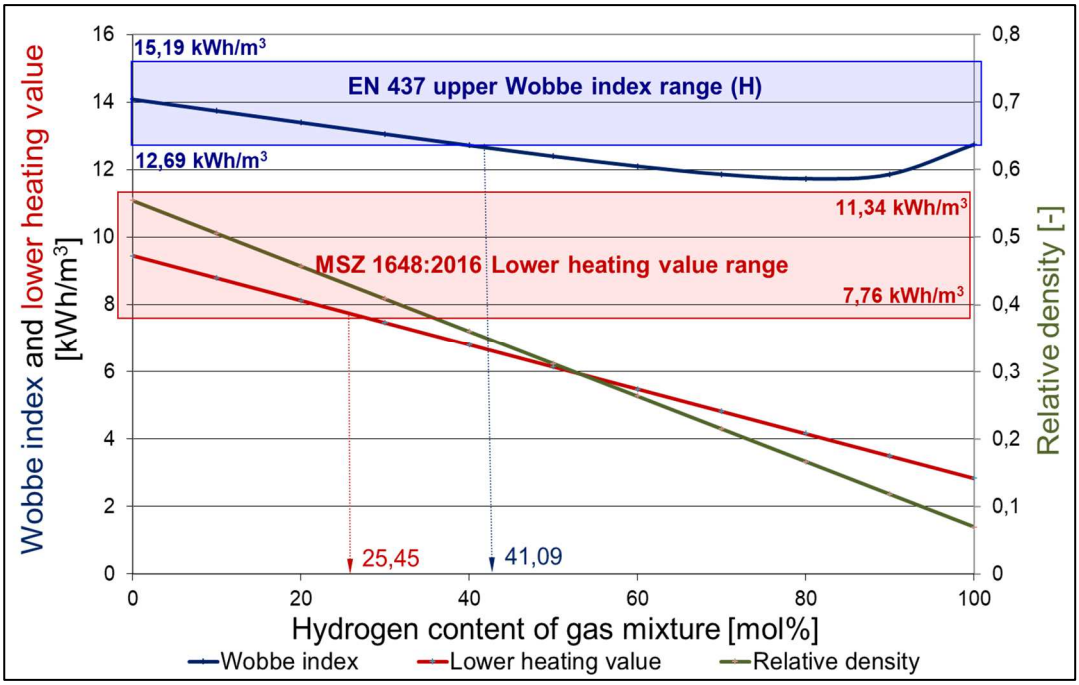

Figure 2 Combustion characteristics of methane-hydrogen gas mixture

3 Gas quality characteristics of hydrogen and natural gas

Table 1 shows the physical and combustion properties of hydrogen and a typical Russian natural gas. The parameters that can be the source of the problem during the fire are clearly shown in the table. Because hydrogen has a very low relative density compared to air (Figure 2), therefore, in case of leakage, it is much easier to separate from methane and form explosive medium in the setting room.

Table 1 Comparison of combustion properties of hydrogen and natural gas [7-9]

Properties	Unit	Hydrogen (H_2)	Natural gas (2H russian)
Molar weight	kg/kmol	2.016	16.409
Density (15 °C; p_n)	kg/m³	0.090	0.695
Relative density	-	0.070	0.567
Lower heating value (15/15 °C)	kWh/m³	2.840	9.501
Upper heating value (15/15 °C)	kWh/m³	3.362	10.548
Lower Wobbe index	kWh/m³	10.496	12.613
Upper Wobbe index	kWh/m³	12.744	14.002
Laminar ombustion velocity	cm/s	~267	~34
Flammability limits (20 °C)	V/V%	4.0-77.0	4.3-15.6
Theoretical oxygen volume	m³/m³	0.499	2.014
Theoretical air volume	m³/m³	2.383	9.614
CO_2 emission	m³/m³	0,001	1.009
Methane number	-	0,0	92.5

Its energy content per unit volume is only a third of that of natural gas, but its Wobbe number, one of the most characteristic parameters of gas mixture interchangeability, is only 9.5%. The most important difference is the rate of flame propagation of gases and the ranges of ignition concentrations, as hydrogen burns 10.5 times faster in the air than natural gas. When fired in gas appliances, this will be one of the most decisive variables, which will severely limit the allowable mixable quantities.

A very significant shift in the ignition concentration limit towards the upper limits indicates the danger of hydrogen gas flowing into the environment or fire field. (Figure 3) It can be seen that the lower ignition concentration limit is almost unchanged, but the upper limit increases exponentially with the enrichment of hydrogen.

The minimum ignition energy of hydrogen is about 10 times lower than methane, i.e. much easier to ignite, but their self-ignition temperature is quite similar (H_2: 560 °C; CH_4: 595 °C) [1]. As a result, natural gas-hydrogen mixtures can become more easily ignited, thus increasing a higher risk of explosion.

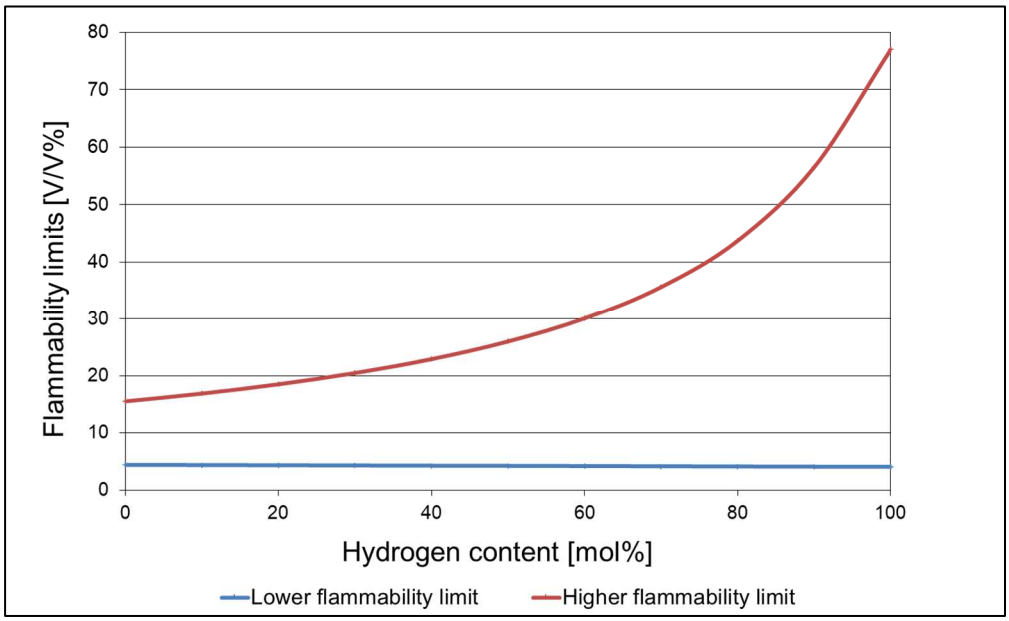

Figure 3 Flammability limits of methane-hydrogen mixture

4 Pollutant emissions

In the operation of the devices, it would be advisable to use a natural gas-hydrogen mixture in order to reduce the amount of carbon dioxide that is going into the atmosphere from the burning of fossil natural gas. Figure 4 shows CO_2 emissions in g/MJ calculated on the basis of the theoretical air volume and the lower heat value of the gas. The CO_2 emission value of pure methane 58.03 g/MJ (15 °C; pn) may be reduced to 0.13 g/MJ using pure hydrogen. Note: the minimum carbon dioxide content of the hydrogen combustion product is not zero due to the carbon dioxide content of the air used for combustion. For the maximum blending rate of 25% tested by us, a value of 52.73 g/MJ can be achieved, resulting in a saving of 5.3 g/MJ. In Hungary, in 2018, the quantity of natural gas transferred to residential customers during domestic sales was 115,084,720 GJ, equivalent to 3.36 billion m^3 for the average annual lower heat value of natural gas at a combustion and measurement reference state of 15/15 °C. The average lower heat value is calculated on the basis of MEKH statistics on energy content (GJ) and volume unit (em^3) [2].

During the research, we conducted studies on how much CO_2 emission reductions can be achieved during the replacement of natural gas with hydrogen, based on residential natural gas use in 2018. In the year under consideration, as a result of gas consumption in the residential sector, 6,623 thousand tonnes of CO_2 were added to the atmosphere, accounting for 14.7% of the country's total CO_2 emissions that year [10]. Chart 5 shows the extent to which CO_2 emissions can be saved by increasing the supply of hydrogen to the natural gas network and its use in residential gas-supplying appliances. In 2018, the replacement of 1 mol% of the amount of natural gas consumed by the residential sector to hydrogen (in terms of energy content) will save 19.8 thousand tonnes of CO_2 emissions, which represents 0.04% of the carbon dioxide emissions generated by Hungary in the year under review. The use of natural gas with a hydrogen content of 5 mol% is already 102.1 thousand tonnes, while gas with a hydrogen content of 10 mol% results in a decrease in CO_2 emissions of 211.8 thousand tonnes based on residential natural gas consumption in 2018. If the 25% hydrogen content of natural gas had been tested earlier, the CO_2

emissions measured in 2018 would have already decreased by 9%.

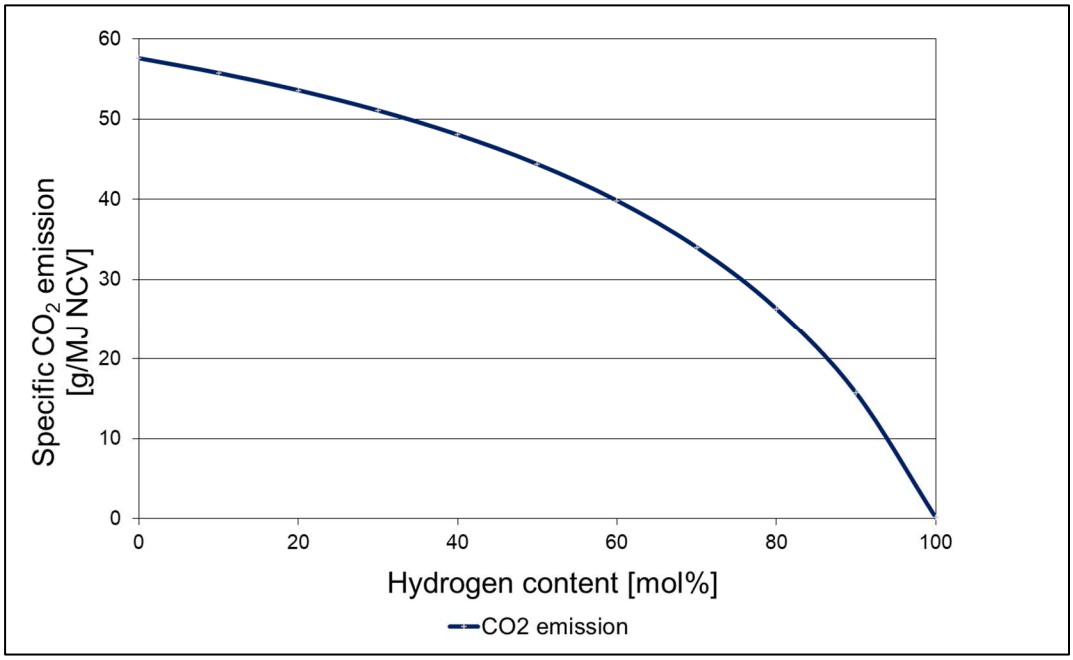

Figure 4 Evolution of the specific combustion-related CO_2 emissions of methane-natural gas mixture

In addition, it is important to note that hydrogen has a significantly lower energy density than natural gas – approximately only 30 % – and therefore requires a higher amount of methane-hydrogen gas mixture to achieve the same output. As can be seen in Table 2, the replacement of natural gas supplied to the residential sector in 2018 to 1 mol% hydrogen (in terms of energy content) will increase residential consumption in that year by 79 million m^3, while for 10 mol% hydrogen content it will mean 790 million m^3 of additional gas, which is nearly 24% higher than the amount of residential natural gas consumption in m^3 unit in 2018. Natural gas with a hydrogen content of 25 % increases the consumption of natural gas by approximately 2 billion m^3 in the year under consideration, and a hydrogen molecule would constitute 52.8 V/V% of the resulting 5.33 billion m^3 natural gas-hydrogen mixture. In the year under consideration, the total consumption of natural gas by hydrogen requires the production of 11.26 billion m^3 of hydrogen gas, which is 3.35 times the volume of natural gas originally supplied.

In addition to CO_2, only carbon monoxide and nitrogen oxide emissions are relevant for combustion-related emissions. Carbon monoxide (CO) is basically formed due to imperfect combustion i.e., too little combustion air surplus, or too high a fire field temperature. If these factors can be eliminated from the process, the amount of formation will not be decisive. If the air supply of the appliance is not re-regulated when hydrogen gas is fed, excess air will not allow carbon monoxide to form. The temperature of the fire field is proportional to the flame temperature, at which we saw that it does not increase significantly with up to 25% hydrogen mixing i.e., this factor is not really relevant either. However, it should not be ignored that excess air that is too high cools the fire area, making the flame increasingly unstable, which can lead to locally imperfect combustion i.e., carbon monoxide formation.

In the case of natural gas burning, the formation of nitrogen oxides due to thermal i.e., high fire field temperatures, can be decisive. The appearance of hydrogen in the mixture results in higher combustion temperatures and higher excess air, so more oxygen is available in the reaction zone. Since the increase in the hydrogen share also reduces the energy content of the gas per unit, the energy released, and with it the fire room temperature, will be lower if we do not change the amount of gas that led to the burner. It can be a typical situation in the residential sector. This also reduces the likelihood of nitrogen oxides forming.

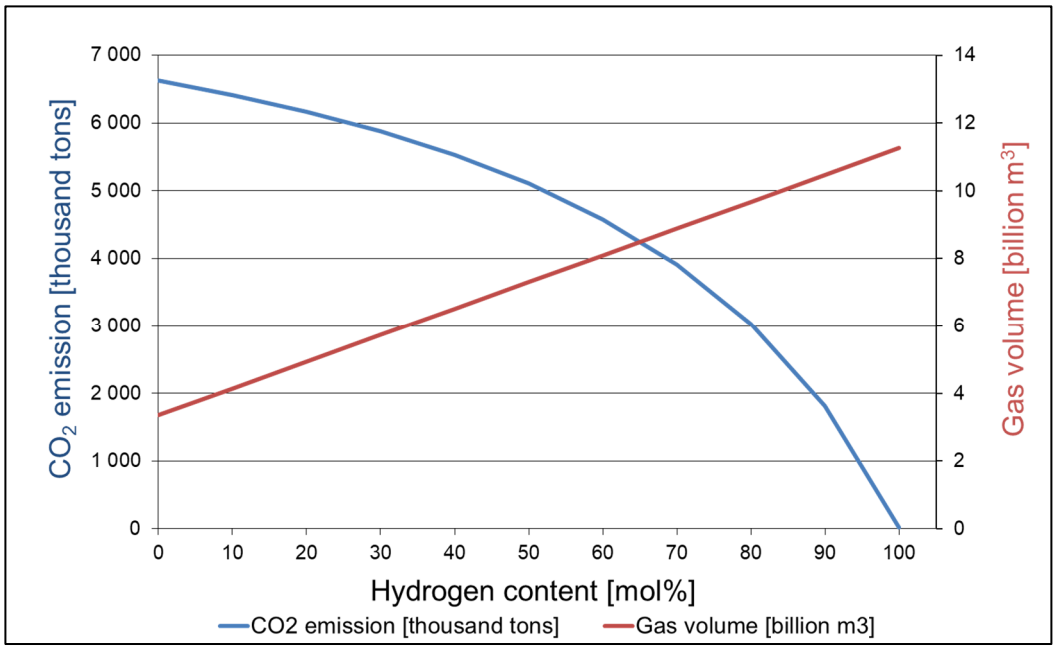

Figure 5 Theoretical CO_2 emissions savings by blending hydrogen into natural gas system in Hungary

Table 2 Replacement of natural gas with hydrogen in terms of energy content

	Domestic sales to residential users	1 mol% H_2 replacement	5 mol% H_2 replacement	10 mol% H_2 replacement	25 mol% H_2 replacement	100 mol% H_2 replacement	Unit
Natural gas	3 355 631 000	3 322 074 690	3 187 849 450	3 020 067 900	2 516 723 250	0	m^3
Hydrogen	0	112 571 726	562 858 629	1 125 717 259	2 814 293 146	11 257 172 585	m^3
Gas mixture	3 355 631 000	3 434 646 416	3 750 708 079	4 145 785 159	5 331 016 396	11 257 172 585	m^3
Average lower heating value	9.527	9.460	9.192	8.858	7.855	2.840	kWh/m^3

5 Conclusion

Hydrogen mixed into the natural gas network may be an appropriate environmentally friendly alternative to the partial replacement of natural gas, but the physico-chemical and combustion technical properties and safety conditions of the mixture, even significantly different from natural gas, should not be ignored. Combustion theory tests are forward-looking in terms of applicability, but on their own they can only provide support and guidance, they cannot replace the actual device tests. It is clear that the question must be answered before it is actually used in the residential gas consumer sector.

We need to distinguish between gas equipment techniques equipped with an automatic combustion control system, i.e. they can be adapted to varying gas quality to a certain extent, as well as the large number of gas appliance parks, mainly residential, in which, on the one hand, there is no automatic control system and, on the other hand, it contains a significant number of partial pre-mix burners. In this case, in addition to the changing gas composition, the excess air does not, or only minimally, change, while the energy content of the fuel is even more significant.

Hungary natural gas use, the retail sector plays a prominent role. As a consequence, significant attention should be paid to end-user equipment prior to the release of hydrogen on the natural gas network. The studies have clearly shown that the appearance of hydrogen on the natural gas network results in a not insignificant reduction in CO_2 emissions. Looking at the consumption of natural gas by the public in 2018 with the replacement of 25 mol% hydrogen content, the annual emissions of CO_2 Hungary have been reduced by nearly 10%. In addition, it should be noted that due to the lower energy content of hydrogen compared to natural gas, a higher gas volume is required to achieve the same output.

Hungary natural gas use, the retail sector plays a prominent role. As a consequence, particular attention should be paid to end-user equipment prior to the release of hydrogen on the natural gas network. In 2018, the replacement of 1% of natural gas consumed by the residential sector to hydrogen will result in a reduction in CO_2 emissions of 0.3% and 10% hydrogen by 3.2%.

It can be said with great probability that hydrogen mixed in natural gas is strongly suited to the

decarbonisation of the residential energy sector, but the restrictive requirements dictated by the existing gas appliance park should also be strongly taken into account. The mixture does not pose a safety and fire risk up to a certain composition limit, but the high hydrogen share will clearly only be available by replacing the existing equipment fleet.

Acknowledgement

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DCT AND MLP IN THE APPLICATION OF MAGNETIC FLUX LEAKAGE DEFECT DETECTION

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Keywords: Non-Destructive Testing (NDT), magnetic Flux Leakage (MFL), Multilayer Perceptron (MLP), discrete cosine transform (DCT)
Abstract: Non-Destructive Testing (NDT) is known as a harmless technique for industrial pipeline cyclic inspection. This way tries to find out defected parts of a device used in industry with a test by means of non itself destroying. Many ways are known and employed in NDT procedure. MFL or magnetic Flux Leakage is one of well-known and so efficient ones is widely used to find out defects in metal surface. Emission of magnetic field into device surface and recording reflected emission lead to complete a database of defect and no defect for an especial task. Then mathematical equations could help to provide normalization and classification ahead. Defect and non-defect detection are an essential and cost loss technique for analyse data from cyclic inspections. For this purpose a combination of neural networks is designed and trained in the best performance and with optimum accuracy rate. In this model Classification is done via Multilayer Perceptrons (MLP). Two level of classification is applied. First defect categorization and then defect or non-defect detection. In this paper a mathematical function named DCT or Discrete Cosine Transform is applied in pure database for data compression. This function provides a view on database in real component of frequency domain. By composing DCT function with a neural network group, this algorithm provides 97.3 percent accuracy rate in defect detection of MFL signals.

1 Introduction

Classification of defects, recognition and detection of them is a very useful and costless solution in all fields of industry. As far as 30 years ago, there becomes a try to find destroyed point of a surface without harmful ways. NDT or non-destructive testing was founded as a liable solution and non-destructive way to provide an analysis of devises surfaces. In this way many papers try to expose and design a liable algorithm to provide intelligent defect detection. This way is efficient by two main tasks. First is illustration of an intelligent algorithm and second is an exact decision without harm the main surface of device. First step in this paper is a combination of neural networks and a compression function. DCT known as Discrete Cosine Transform is one of well known ways to compress and extract main indexed data from a pure database. In this way more indexed data are collected in squared matrixes from main normalized data of NDT signals. Combination of DCT matrixes from main database is used to calculate the result and best choices are considered and reported in table 1. Output of DCT function is a compressed indexed data that is suitable to be used for classification. Two main groups of classes are combined to perform a special decision task on defect type and detection of them for a metal pipeline.

In this paper analytical functions that could simulate NDT signals achieved from surface of metal, becomes in sight of view [1].

MFL known as magnetic Flux Leakage that is presented before is one of NDT ways that focuses on return reflex of magnetic emissions on a metal surface. This way is so important and efficient to use in many fields of industry [2-10].

The other important point is nonlinear procedures that may use in intelligent algorithms. Linear and nonlinear mathematical functions help main idea to apply a more reliable and more efficient output [11-22]. This paper tries to classify defects by the rate radius however there are another way such as depth consideration [23,24].

In this paper with regards to previous approaches, performs a new combination of neural networks to provide an efficient classification on MFL database of NDT procedure [19-22]. This paper exposes two levels of networks. First step tries to find out defect type from its physical dimension and second network tries to detect defect and non-defect in final decision.

2 Database of defects from MFL testing

When a metal surface is magnetized near saturated, Magnetic Flux Leakage that reflected from saturated surface could be presented in equation (1) [2,3].

$$H_y(x,y)=\frac{2xy\left(m-2H_a a^2\right)}{\left(x^2+y^2\right)^2} \quad (1)$$

In this equation, *m* is the dipole moment per unit length and it could be calculated as follows (2):

$$h=1.05\times10^{-34} \quad m=\frac{\sqrt{3}}{2}h \quad (2)$$

In this formula h is Plank coefficient. And H_a is the magnetic flux that applied to the surface in purpose of reflex flux measurement. This coefficient is 1 Tesla. *a* which presents the radios of defects is a parameter that is very important in our paper calculation. This value is further more used as fundamental task of this paper algorithm and classification. [11-13]. In this paper *y* is constant and is equal to the depth of the defect that is mentioned *h*. therefore magnitude of *h* specifies depth of defect. Also by some nominations to equations, *p* and *q* could be summarized as $p=2h(m-2H_a a^2)$ and $q=h^2$ therefore equation number 1 is summarized and exposed in equation (3):

$$f(x)=\frac{px}{\left(q+x^2\right)^2} \qquad (3)$$

In measuring devises the story is a bit different. First inducted coils emit a magnetic flux to the surface via coils and then reflected signal is recorded. Therefore production of device velocity and derivation of *f(x)* in *x* direction is recorded. So MFL signal is exposed in equation (4).

This way could expose a view for MFL signal in time and direction. However in this way and in follow dept of defects could be considered.

$$F(x)=v\cdot f'(x)=v\left(\frac{p}{\left(q+x^2\right)^2}-\frac{4px^2}{\left(q+x^2\right)^3}\right) \qquad (4)$$

3 Compression by DCT

Discrete Cosine Transform, DCT, is a Fourier based function that when applies to a pure matrix, gathers more information in first its elements. Therefore components of DCT matrix which are located top left are denser in information collected from a pure matrix. DCT is natural shaped square and when anyone wants to use a part of this matrix as for compression purpose, then should select a square matrix from top left.

Discrete Cosine Transform could be known as a part of Discrete Fourier Transform (DFT), DFT has two main parts. One is a Cosine function and another is sinus function and this can be said that DCT, is a main cosine part of DFT. This main part is made up of real components of a DFT with an even function in purpose. This function (5) is a strong function in data compression and sometimes called "energy compaction function". This property is a ppoint to use this function in signal processing as a liable and an effort able tool [4].

$$X_k=\sum_{n=0}^{N-1}x_n\cos\left[\frac{\pi}{N}\left(n+\frac{1}{2}\right)k\right] \qquad (5)$$
$$k=0,\ldots,N-1$$

For our reason this function is employed because if its strong behaviour on collecting the important information in low frequencies at the top left of the DCT matrix. The squared low dimensional matrixes could lead to best and rapid decisions in some cases this later could lead to the accuracy rate of 93.1% in total decession.

3.1 Classification for recognition

In this paper a combination of neural networks are used to perform a suitable and affordable decision on defect, non defect and also defect physical shape.

Two main steps are mentioned. First one is to recognize the type of defect. In this case three classes are trained to recognize three defect types. All three classes are trained at the best of efficiency with different epochs and iterations but for provide a table to compare with others all three experts should be trained at same number of iterations. So in this way may some classes not perform at the best but are adequately acceptable.

Experts here are all Multilayer perceptrons (MLP), with tansig and logsig functions in hidden layers. Experts for defect types, have one hidden layer with tansig function [17,18]. These experts are trained to recognize a defect type. And the other hand is a network with two hidden layer. Output is a node that performs a digital task. YES or NO. output could be named as defect danger or not. Two hidden layers are responsible to perform a boundary between defect shapes; dept and surface of defects are recognized and categorized by this expert. So the output performs that defect is still in range of safe or not. Whenever defect size change to bigger surface or dept, this network wills response to 0 or 1 in regard to what system required in training phase.

DCT (Discrete cosine transform) is right one step before classification that was the main goal of this research. A mathematical solution to decrease dimensions of pure MFL data. It should be notified that the pure database is normalized. One another point when using mathematical functions to compress the data is the number of attributes of that function by which selected. Many wide ranges of attributes of course perform a better accuracy in data recognition and database reconstruction but amount of software analysis will increase and this is not good in algorithm designation. So, select an efficient number of DCT matrix is another important task. This paper focuses on networks analysis and what is important and is efficient in algorithm design. Table 1 Shows result of experimental activities in training phase.

DCT AND MLP IN THE APPLICATION OF MAGNETIC FLUX LEAKAGE DEFECT DETECTION
Saeedreza Ehteram

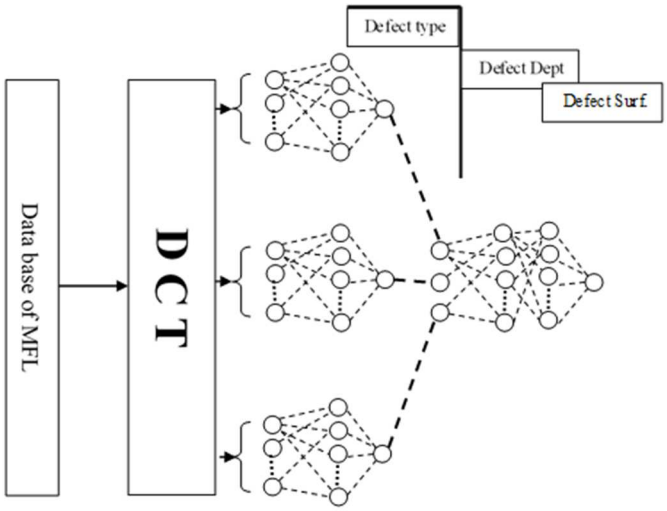

Figure 1 Algorithm scheme

3.2 Experimental approach

Please note that all the above quantities are approximated by less than 0.1 differences.

This table (Table 1) tries to show result and compression of algorithm shown in figure 1. Here is three networks that are feed by a database for providing a classification for categorizing MFL signals in three groups.

Table 1 Experimental research

									MAIN NETWORK →						FINAL DECISSION		
NET. Hidd. Layer									NET1		NET2		NET3				
DCT									Hidd		Hidd		Hidd		L1	L2	RES
								1	4	43.0	4	31.5	4	45.0	3	3	91.3
							2		5	55.0	5	40.5	5	61.3	4	4	91.5
						3			6	67.3	6	53.6	6	71.6	5	5	90.6
					4				7	73.3	7	70.1	7	77.4	6	6	89.0
				5					8	80.3	8	79.9	8	83.3	7	7	93.1
			6						7	83.6	7	80.3	7	88.5	6	6	91.3
		7							6	79.9	6	78	6	80.0	5	5	90.3
	8								5	79.3	5	77	5	77.5	4	4	91.0
9									4	77.6	4	70.3	4	72.7	3	3	91.3
5									**8**	**80.3**	**8**	**79.9**	**8**	**83.3**	**7**	**7**	**93.1**
BEST Choice																	

For data comparison, DCT is applied to database of MFL signals to compress and select valuable data indexes in DCT square matrix. DCT provides an important square matrix. But all of DCT matrix equipments will not used due to data compression. For data compression a number of squared components is selected each time and results are combined with other numbers and all are collected in table 1. For more information mentioned squared matrix in then filled with 1 to reach an acceptable dimension regards to mathematical multiplication rule. Then matrix of data that DCT is applied on it is ready to be classified in next step. Next step is classification with three classes. Class number one to three are trained to recognize defect surface of 0.000314 m2, 0.001256m2 and 0.002826m2. These defect sizes are in respect for defects of radios 0.01 m, 0.02m and 0.03m. Best result of training and test for these three classes are recorded in table 1. These results are achieved by at least 30 times training by different hidden number of nodes and the best one is recorded in table. These networks are MLP with tansig and logsig functions in hidden and output layers in respect. output layer is our final network that is designed to recognize defect from non-defect. Result shows that when defects are recognized first by three networks before, final result is better. There for at the end an overall response of network for 93.1% is achieved by the application of 7 nodes in hidden L1 and L2 layers.

4 Conclusion

This paper introduces a simple and efficient algorithm for defect detection from MFL signals of NDT inspection. This way is based on pattern recognition and signal processing solutions. Here two main steps are defined. First data compression via DCT and second Classification by a combination of MLP neural networks. in this research, defects are categorized in three parts with focus on their surface physical shape with radios long of 0.01 m, 0.02 m and 0.03 m. neural networks in classification part are designed to work in two non-separated tasks. Defect type and defect or non-defect task. The accuracy rate of 93.1 percent totally in defect and non-defect test shows ability of this simple algorithm.

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STATISTICAL DEVELOPMENT OF TRANSPORT WHICH REFLECTS THE NEED FOR CATALYSTS

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Abstract: This paper deals with the analysis and expected development of freight transport and especially road freight transport in Slovakia and in the European Union. Transport, which ensures the movement of goods, animals and people in all countries around the world, has a significant influence on the development of the national economy. However, this development of transport has a negative impact on the global ecological situation, and therefore devices, that eliminate this impact, are still developing at the same time. These devices include catalytic converters (catalysts) for exhaust systems fitted to all modern propulsion systems of road, rail and water vehicles that use burning petrol or diesel. Based on the development of transport, the need for catalysts is derived, which still use elements of the PGMs (Platinum Group Metals). The result of the article is an analysis and expected predicted development of freight transport and road freight transport in both cases - in Slovakia and in the EU, which will affect the future demand for PGMs.

1 Introduction

Transport is characterised among the oldest and most important human activities, which is extremely important for the development of society. Freight transport is an important factor in the economy as a part of material production and logistics. By providing a link among the areas of production, circulation and consumption, it unites geographically separate areas of production and consumption. In the field of freight transport, in terms of transport demands, the mutual relationship of the individual components of the production chain can be considered: a source of raw materials - a source of necessary energy - a manufacturing company - a market, is essential in the production process. Transport is an integral part of almost every technological process. The technical level of transport should correspond to the technical level of other machinery and equipment so that a situation of slowing down the technological process does not arise. Transport processes can clearly and directly affect the performance and economic results of the manufacturing process in a production organization [1].

There are different types of used means of transport [2]:

- Road and urban public transport.
- Railway.
- Air.
- Water.
- Combined.

The road transport, together with the rail transport, forms the basis of the transport system in the EU as well as in Slovakia. Just the road freight transport is targeted by this paper, because it plays an important role in the development, production of catalysts for HDV (Heavy-Duty Vehicles) and consumption of PGMs (Platinum Group Metals) [2].

The road freight transport transports the most goods in tonnes and achieves the highest degree of transport performance in tonne-kilometres. It allows the widest market coverage, its flexibility is influenced by the density of the road network. Due to its versatility, it best meets customer requirements. The road transport is irreplaceable in flexibility, efficiency and time savings. It is the most often used to transport building materials, parcels, cereals, animals, solid fuels and other shipments. It is one of the most important transport modes within the logistics [3].

The railway transport is the second important mode of transport and it is suitable medium and long distances, especially for bulk and extensive deliveries in complete trains. The most frequently transported goods are fuels, ore, wood, building materials and other types of goods that do not matter the speed of transport. Rail transport must be combined with other modes of transport, mostly with the road transport. Among the disadvantages of railway transport, it is included a high demand for investment funds in the transport route, security equipment, locomotives, wagons, loading stations, etc. [4].

2 Methodology

The aim is to achieve a hypothesis about the future situation of transport development, which is based and focused on methods associated with forecasting. It can be said with certainty that forecasting is a regular examination of the future and the formulation of scientific claims about possible versions of future developments. In practice,

forecasting becomes a part of the management and planning process. New knowledge is gained about future facts and processes by the forecasting. It facilitates communication among the representatives from different fields, such as e.g. administration, science, civic movement and governance through an illustrative form for a user. It also includes the promotion of results in prognostic practice [5].

2.1 Transport forecasting

The basis of the transport forecasting is the specification of requirements for the transport infrastructure and the entire transport system. It is the most complex part of the transport forecasting process and must cover all aspects of development, all traffic modes and the possibilities of multimodality and intermodality. Traffic forecasts are divided into four groups according to time horizons:

- Short-term up to 5 years.
- Middle-term from 5 to 10 years.
- Long-term from 10 to 25 years.
- Extra long-term forecasts over 25 years, normally up to 30 years in accordance with the provisions of STN standardisation.

Sophisticated mathematical procedures are used for transport forecasts, but the personality of the prognosticator and his experience plays important roles in their quality. In terms of accuracy, forecasts over 10 years are very strongly dependent on the amount and quality of input data and also on the stability of the economic situation. Forecasts over 25 years can be considered as indicative [6,7].

2.2 Methods of forecasting

Regression analysis: Regression analysis examines the relationship between two or more random variables. It most often examines the dependence between two quantities, when *X* is called an independent variable and *Y* is a dependent variable. This dependency (1) can be write as:

$$y = \varphi(x), \qquad (1)$$

where $\varphi(x)$ indicates a function that describes a given dependency.

In most cases, this function cannot be expressed by any description, so a function is sought that best describes the dependency. If this dependence is found, then it is possible to estimate the value of the dependent quantity *Y* by any independent quantity *X*.

The dependence between the quantities is influenced by various random influences, which are called noise. In some cases, the magnitude of the noise may be large, and in other examples it may be very small. The mean noise value is assumed to be zero [7,8].

Exponential smoothing: Exponential smoothing (2) is a method of intuitive prediction that weighs the observed time series unevenly. Recent observations have higher weight than older ones. Uneven weighing is performed using one or more parameters that determine the severity of each observation.

$$F_{N+1} = \alpha Y_N + (1-\alpha)F_N \qquad (2)$$

Exponential smoothing models are widely used methods in time series analysis. This popularity can be attributed to their simplicity, computational efficiency, accuracy, and ability to adapt to changes in the prediction process. In general, exponential smoothing is a simple technique that gives a good forecast in a wide range of applications. In addition, the requirements for data storage and computing are minimal [8].

Holt method: Holt linear exponential smoothing is a modification of simple exponential smoothing in which two smoothing constants are used:

- To create the level of a given series of smoothing constants (α);
- For the direction compensation constant (β).

Due to the different trends in individual data, simple exponential smoothing is able to process some interesting and important non-stationary processes in these trends. E. S. Gardier explains as C. C. Holt, whose model also includes trends in time series. The final formula (3) for the prediction contains the mean coefficient and the trend coefficient together with the functional error (ε):

$$F_{N+p} = L_N + pT_N + \varepsilon \qquad (3)$$

This formula consists of two sub-equations for smoothing of two parameters of the equation, namely the mean (level) coefficient L_t (4) and the trend coefficient T_t (5). The current equation for the middle level of the equation is a version of simple exponential smoothing. As the trend coefficient has been added to the previous interruption for component formulation, it will get an exponential decrease in the impact of the current observation. The process has been extended one step backwards along the timeline [8].

Mean (level) coefficient:

$$L_N = \alpha . Y_N + (1-\alpha)(L_{N-1} + T_{N-1}) \qquad (4)$$

Trend coefficient:

$$T_N = \beta(L_N - L_{N-1}) + (1-\beta)T_{N-1} \qquad (5)$$

3 Results

In the following section, this paper provides an analysis of the development of transport, which is focused on road transport, because this type of transport has the significant

impact on the production of catalysts and the consumption of PGMs, as the basic natural resources.

The development of road transport is reflected by amount of transported goods. In this way, the data that forms the time series are recorded. In the first case, the forecast is devoted to developments in Slovakia and in the second case is the forecast of developments in the European Union. Due to the comparison of individual results for Slovakia and EU, the main indicator of traffic intensity is the selected traffic performance in units of tkm (tonne-kilometres).

3.1 Development of the road transport in Slovakia

In Slovakia, as well as in other EU countries but also in all countries around the world, the road freight transport forms the main freight transport. Although many activities are being taken to reduce road freight transport and subsequently shift it to another mode of transport, the constant increase in demand for the transport of goods does not reduce this trend much in reality. The subsequent overview of the development of transport and the forecast in Slovakia is the proof of this fact - Table 1 and Figure 1. The forecast is made for the next 5 years and to increase objectivity, the forecast is made by two traditional methods and their results are combined as follows: 50% Holt + 50% Linear regression.

Table 1 Development of transport in Slovakia
Source: https://slovak.statistics.sk

	Total freight transport	Road freight transport	Forecasts		
Year	millions tkm	millions tkm	Holt millions tkm	Regression millions tkm	Combination millions tkm
2009	35678	27484			
2010	37682	27411			
2011	38029	29045			
2012	38173	29504			
2013	39245	30005			
2014	40849	31304			
2015	42745	33525			
2016	46075	36106			
2017	44724	35362			
2018	44873	35590			
2019	43318	33888			
2020			34995	37225	**36110**
2021			34805	38137	**36471**
2022			34615	39050	**36833**
2023			34425	39963	**37194**
2024			34235	40876	**37555**

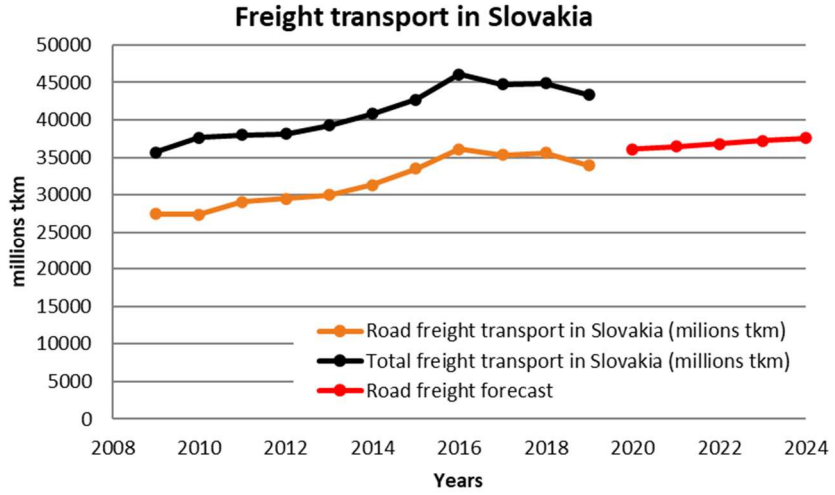

Figure 1 Graphic overview of the development of transport in Slovakia

3.2 Development of the road transport in EU

The development of the freight transport in the EU is similar as in Slovakia. The subsequent overview of the development of transport and the forecast in Slovakia is the proof of this - Table 2 and Figure 2. And again the forecast is made for the next 5 years and to increase objectivity, the forecast is made by two traditional methods and their results are combined as follows: 50% Holt + 50% Linear regression.

Table 2 Development of transport in the EU
Source: European Commission (2019). EU transport figures. Statistical pocketbook 2019, Luxembourg: Publications Office of the European Union

Year	Total freight transport billions tkm	Road freight transport billions tkm	Forecasts Holt billions tkm	Regression billions tkm	Combination billions tkm
2009	3292	1607,3			
2010	3462	1709,9			
2011	3488	1699,1			
2012	3394	1645,3			
2013	3434	1670,8			
2014	3480	1677,0			
2015	3504	1713,7			
2016	3661	1803,5			
2017	3745	1848,6			
2018	3883	1798,7			
2019	3953	1816,6			
2020			1848,2	1846,9	**1847,6**
2021			1862,3	1867,0	**1864,7**
2022			1876,4	1887,1	**1881,7**
2023			1890,4	1907,2	**1898,8**
2024			1904,5	1927,3	**1915,9**

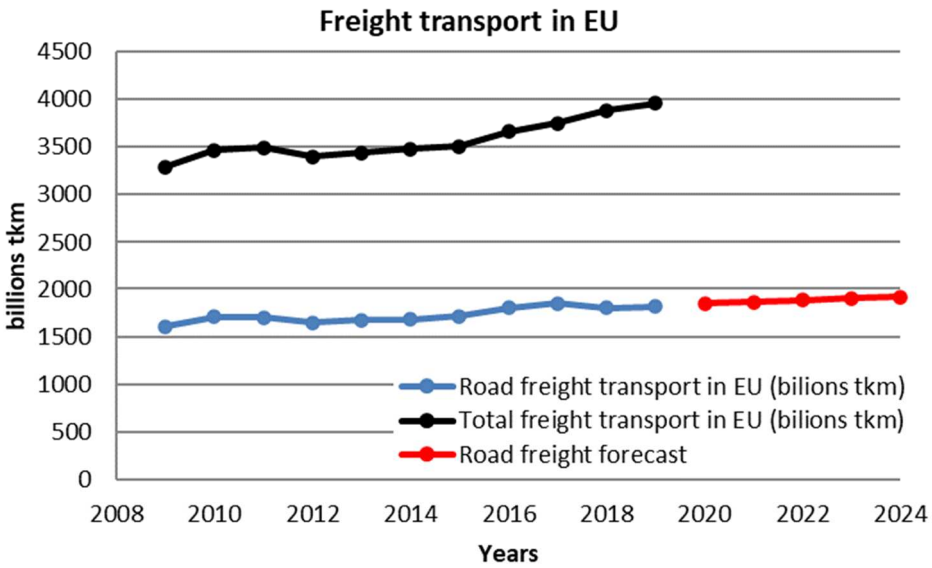

Figure 2 Graphic overview of the development of transport in the EU

4 Conclusion

Forecasts in both cases show a positive trend in the development of transport not only in Slovakia but also the EU. The forecasts do not include the current impact of the pandemic situation caused by COVID-19, which was spread out worldwide in 2020. It is expected that the declination in traffic and thus its performance will fall by about 6%. This declination is caused mainly by the shutdown of industry and thus the economies in the first wave of the pandemic crisis. In the second and in some other waves, this declination is minimal, because although lockdowns have been introduced again in many countries, the industries have not been shut down and the main

engines of the economies have not been greatly weakened. In any case, even after the end of this COVID-19 crisis, the demand for freight and thus also road transport is expected to increase even more. This directly means an increase in demand for minerals, especially PGM's for the production of catalysts. Therefore, current research in the world is focused not only on the recycling of these PGM elements but also on the development of technologies that could replace these elements in the future in order to minimize costs and environmental impacts.

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