ŠKODA AUTO University

ICAI 2022

INTERNATIONAL CONFERENCE ON AUTOMOTIVE INDUSTRY 2022

Proceedings of the
2nd International Conference
on Automotive Industry 2022

June 9 - 10, 2022
Mladá Boleslav
Czech Republic

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FOREWORD

Ladies and gentlemen, dear readers,

As predicted by one of the invited speakers at the opening panel of the International Conference on Automotive Industry 2020, the automotive industry is experiencing an even more challenging period in 2022 than that which it faced at the beginning of the Covid era, especially in Europe. It is facing new challenges to find the optimal configuration of value and supply chains. Among these challenges, aspects of European security and self-sufficiency come to the fore. These challenges are demanding enough in themselves, not least because the dominant global market is, and will remain for some time to come, the Asian market, where the advantage of size (scale) has been successfully transformed into technological advancement. Despite this, Europe is the second largest automotive market and is striving to respond not only to problems in the current supply chain configuration, but also to challenges connected with climate change. Here, with establishment of the appropriate regulatory frameworks, national and supranational economic policy in Europe is, in addition to well-developed regulation, establishing support through targeted measures within National Recovery Plans. Technical and technological development brings opportunities for the automotive industry in a number of areas, such as utilisation of new materials or the introduction of digital and information technology elements. Together with the introduction of new business models, including the sharing economy, all of the above-mentioned thematic areas also bring with them challenges to modernise the legal framework – these can be issues relating to liability during operation of autonomous vehicles, regulation of emissions or protection of competition, etc.

All of the above-mentioned issues are naturally also today, at the beginning of the Czech EU Presidency, converging at ŠKODA AUTO University, where the individual departments are living and breathing these topics. Although the University is still young, it has already become an established part of international academic networks. We believe that organisation of the International Conference on Automotive Industry (ICAI) – this year with the subtitle "European Automotive Industry at the Crossroads" – at our university is yet another step, which will help to facilitate exchange and sharing of information in the given thematic areas. We hope that the conference will be a suitable platform for their discussion and will prove to be a valuable source of information for all those who deal with issues relating to the automotive industry.

We wish you an inspiring experience.

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Alternative fuels infrastructure deployment under EU law

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Abstract

Resume of 6-year-long application of Dir. 2014/94/EU on Alternative Fuels Infrastructure shows significant underdevelopment of the EU market in this field. The difficult experience of implementing this directive (24 infringement cases opened for non-transposition) shows the need for its revision. Apart from that, support for alternative fuels and more charging stations for vehicles is one of the Fit-for-55 priorities in industry and transport. Accordingly, this work deals with implications of planned replacement of the current directive with the new Regulation on Alternative Fuels Infrastructure. To begin with the choice of reg. (instead of dir.) as a legal instrument in the light of subsidiarity (for non-exclusive competence) and proportionality principles. In addition to this, and above all else - this new reg. is planned to establish clearly binding and directly applicable obligations for member states to ensure their EU-wide coherent and timely application to guarantee the Union-wide roll-out of (re)charging and (re)fueling infrastructure. The deployment of which is crucial for the expected speed of sales of zero- and low-emission vehicles.

Keywords: automotive sector, clean vehicles directive 2019/1161, directive 2014/94/EU, draft regulation on the deployment of alternative fuels infrastructure, Fit-for-55

JEL Classification: K23, K32, K33

1. Introduction

For road transport, the European Green Deal (18.03.2020, COM(2019) 640 final.) sets the objective of having at least 1 million publicly accessible recharging and refueling stations in the EU by 2025. This would establish a springboard for the necessary much larger roll-out of such infrastructure until 2030, as projected in the Sustainable and Smart Mobility Strategy (9. 12. 2020, COM(2020) 789 final.) An important milestone on the Europe's way to zero-emission mobility was Directive 2014/94/EU on Alternative Fuels Infrastructure (OJ L 307, 28.10.2014, p. 1–20, AFID dir.). This directive established a common framework of measures for the deployment of this kind of infrastructure in the European Union. These measures were supposed to be implemented through national policy frameworks and then notified to the European Commission by the 18 Nov. 2016. The national policies based on this directive should contain the following elements: 1) as regards alternative fuels in the transport sector, an assessment of the current state and future market development, including the development of infrastructure with cross-border continuity, where relevant; 2) national targets for the implementation of alternative fuels infrastructure; 3) measures to ensure the achievement of the national targets; and 4) measures that can promote the deployment of an alternative fuels infrastructure in the public transport (Viesi, Crema, Testi, 2017, p. 27355). Although the commented herein AFID directive impacted the number of electric recharging points, which is projected to be around twice as high in 2030 compared to a situation without the Directive, and similar impact was achieved for hydrogen and LNG refueling points, there is still huge necessity for improvement (Naumov, Keith, Sterman, 2022, p. 1–2). Trying to face up to these challenges the Commission has therefore submitted the proposal for a Regulation on the Deployment of Alternative fuels Infrastructure (COM/2021/559 final, AFIR reg.) to the European Parliament and to the Council on 14 July 2021 as a part of the 'Fit-for-55' package. However, for this moment it is only a legislative proposal that is currently being read in the European Parliament and its exact content may still be subject to political agreements and changes, the academic discussion on this far reaching draft is always needed and valuable.

2. Alternative fuels and charging stations for electric vehicles as Fit-for-55 main target

The Fit-for-55 legislative package consists of a set of ambitious, inter-connected proposals, which all drive towards the same goal of ensuring a fair, competitive and green internal market transition by 2030 and beyond. Overall, the package strengthens 8 existing pieces of legislation and presents 5 new initiatives, across a range policy areas and economic sectors, i.e.: climate, energy and fuels, transport, buildings, land use and forestry (14.07, 2021, COM/2021/550 final, p. 5). One of the Fit-for-55 key areas of action in industry and transport sectors is support for alternative fuels and more charging stations for electric vehicles. In order to reach the goal of putting the EU on a path to becoming climate neutral by 2050, a reduction of approx. 90% emissions in transport would be needed. Transport represents almost a quarter of the EU's greenhouse gas emissions and is the main cause of air pollution in cities. Despite of all the efforts aimed at greening EU policies emissions still remain higher than in 1990.

Next to the draft of new AFIR Regulation another Fit-for-55 policy instrument aimed at accelerating the deployment of low - and zero-emission vehicles is the Clean Vehicles Directive 2019/1161 (OJ L 188, 12. 7. 2019, p. 116–130) that is planned for being updated shortly. This initiative is also consistent with the revision of the Renewable Energy Directive 2018/2001/EU (OJ L 328, 21. 12. 2018, p. 82–209. It seeks to ensure that lack of recharging and refuelling infrastructure does not hamper the overall ramp-up of renewable and low-carbon fuels in the transport sector, where they require distinct infrastructure. Emissions-free technologies are still being developed, particularly for heavy-duty road vehicles (Prussi, Panoutsou, Chiaramonti, 2022, p. 1–3).

Consumer demand for zero emission vehicles is already increasing sharply. Almost half a million new electrically chargeable vehicles (ECVs) were registered in the EU in the final quarter of 2020. This was the highest figure on record and translated into an unprecedented 17% market share. It also brought the annual total to one million new ECVs, which means that the existing electric fleet doubled in just 12 months (Quarterly Report of European Electricity Markets, Q4 2020). Electric cars have seen a rapid increase in terms of total vehicle registrations and growth in available models in the period 2010–2020. In the 3rd quarter of 2020, shares increased to 9.9% of all car sales, compared to 3% in the year before. Years: 2019 and 2020 saw a much stronger increase in electric vehicle registrations than in publicly accessible recharging infrastructure deployment. This trend continued in 2020. In fact, in 2019 electric vehicle registrations increased by 50% and in 2020 by 52% in comparison to the previous year, while the increase in recharging infrastructure was only 38% and 30% respectively. While the deployment of faster recharging technology can help to address part of the increased vehicle uptake, continuation of this trend would still imply a serious risk that infrastructure deployment will not go hand in hand with electric vehicle sale in the coming years. This could lead to important shortcomings that can undermine the overall uptake of those vehicles (8.03.2021, COM/2021/103 final, p. 2; Frej, Grabski, Szumska, 2021, p. 2–7).

The major assumption of Action Plan on Alternative Fuels Infrastructure (8. 11. 2017, COM (2017) 652 final) is to guarantee that users can be sure of the capacity and availability of sufficient infrastructure before they decide to buy and use alternatively fueled vehicles or vessels. The deployment of (re)charging or (re)fueling infrastructure needs to be accelerated to follow the expected speed of sales of such vehicles and vessels, otherwise they will not be marketable and their uptake will be delayed. It is equally important to provide clean alternatives for fossil fuel-powered vessels at berth in ports and for aircraft in commercial use stationary at gates or at outfield positions. The pace of deployment of these stations together with their interoperability and user friendliness will again, influence the sale of zero- and low-emission vehicles.

3. The drafted AFIR regulation in comparison with AFID directive

Directive 2014/94/EU on the deployment of alternative fuels infrastructure set out a framework of common measures for the distribution of such infrastructure in the EU. Member States passed national policy frameworks (NPFs) to establish markets for alternative fuels and ensure that an appropriate number of publicly accessible recharging and refueling points is put in place, also to enable free cross-border circulation of such vehicles and vessels on the TEN-T network (the Trans-European Transport Network, Reg. 1315/2013/EU, OJ L 348, 20. 12. 2013, p. 1–128). In particular, the NPFs had to comprise national targets and objectives for the distribution of alternatives fuels infrastructure, taking into account national, regional and union-wide demand. Member States had to transpose the AFID Directive and to notify their NPFs to the Commission by 18 Nov. 2016. There have been lots of delays in the transposition and the Commission opened 24 infringement cases for non-transposition in 2017 and 2018. In the course of 2018 most of the cases were closed and the remaining ones in 2019 and 2020.

In its recent report on the 6-year-long application of this directive the Commission noted some progress in the implementation process (8. 03. 2021, COM/2021/103 final, p. 4). However, the Commission also noticed clearly visible shortcomings of the current policy frameworks: as there is no detailed and binding methodology for member states to calculate targets and adopt measures, their level of ambition in target setting and supporting domestic policies varies greatly. Moreover, the directive's key objective, namely to ensure coherent market development in the EU, has not been met. Shortcomings arise in particular in the following three areas: 1. the lack of a complete network of infrastructure allowing seamless travel across the EU; 2. the need for further common technical specifications to ensure interoperability in light of emerging technologies; and 3. the lack of full user information, uniform and easy-to-use payment methods and full price transparency across the EU. The conclusion of the Commission's report was quite pessimistic – the overall internal market for alternative fuels infrastructure is still in a rather early development phase. For the moment, a comprehensive and complete network of alternative fuels infrastructure does not exist across the EU, though markets are maturing in some parts of the EU. Considering the great relevance of ensuring sufficient infrastructure to support the sale of vehicles and vessels in light of the increased climate ambition for 2030, after this evaluation the Commission recommended retaining the legislation but revising it.

The drafted Regulation on Alternative Fuels Infrastructure proposed mandatory targets that involve new member state's commitments. Finally, it is supposed to ensure the necessary coverage of infrastructure for recharging and refueling cleaner vehicles across the EU, keeping pace with the development of the market and guaranteeing that rural and remote areas will also be covered. These revised rules are the key to ensure legal certainty, increase consumer confidence and provide a clear signal to the industry and car manufacturers.

The Commission made the choice to propose a regulation as a legal instrument instead of another directive. The objectives of this new regulation can be pursued within the framework of a common transport policy and the trans-European networks. The Treaty on the Functioning of the European Union (OJ C 326, 26. 10. 2012, TFEU) establishes the Union's prerogative to lay down provisions for the common transport policy under Articles 90-91, and for the trans-European networks – Articles 170–171 are applicable. Considering the so-called division of legislative powers between the Union and its member states under the above mentioned provisions we may assume the shared powers in the area of transport policy and the supporting powers concerning trans-European networks. The principle of subsidiarity applies, in line with Articles 4–5 TFEU in the areas of so-called shared or concurring competences, or in the fields of Union powers for supporting, coordinating or supplementing measures under Article 6 TFEU (Geiger, Khan, Kotzur, 2015, p. 35-37). With this legal framework in mind, Union action enables better coordination for the even and widespread deployment of alternative fuels infrastructure, instead of relying on member states only. The choice of a regulation ensures a rapid and coherent development towards a dense, widely-spread network of fully interoperable recharging infrastructure in all member states. The Commission's decision concerning the choice of a legal instrument is justified in view of the needed swift and coherent implementation of the national fleet-based minimum deployment targets set at member state level and the mandatory distance-based infrastructure targets along the TEN-T network. We also have to bear in minds that the first proposed targets are planned to be reached by 2025 already (AFIR Reg., p. 7).

The drafted AFIR Regulation will establish new clearly binding and directly applicable obligations for member states at national level to ensure their EU-wide coherent and timely application and implementation at the same time. For instance, drafted Articles 3 and 4 contain targets for electric recharging infrastructure provisions for member states to ensure minimum coverage of publicly accessible recharging points dedicated to light- and heavy-duty road transport vehicles on their territory and on the TEN-T core and comprehensive network. To that end, member states shall ensure that: along the TEN-T core network, publicly accessible recharging pools dedicated to light-duty vehicles are deployed in each direction of travel with a maximum distance of 60 km in-between them (Article 3 (2) AFIR Reg.). Article 6, in turn contains provisions for member states to guarantee minimum coverage of publicly accessible refueling points for hydrogen dedicated to heavy- and light-duty vehicles on the TEN-T core and comprehensive network. To that end member states shall ensure that by 31 Dec. 2030 publicly accessible hydrogen refueling stations with a minimum capacity of 2 t/day and equipped with at least a 700 bars dispenser are deployed with a maximum distance of 150 km in-between them along the TEN-T core and comprehensive network. Liquid hydrogen shall be made available at publicly accessible refueling stations with a maximum distance of 450 km in-between them. Additionally, at least one publicly accessible hydrogen refueling station should be deployed in each town/city. In line with Article 8, minimum coverage of publicly accessible refueling points for liquefied natural gas dedicated to heavy-duty vehicles on the TEN-T network has to be guaranteed until 1 Jan. 2025. It is also worth noting that Article 13 reformulates provisions for member states' national policy frameworks. It will establish closer cooperation between states and the Commission to develop concise planning to deploy infrastructure and meet the regulation targets. It also includes new provisions on formulating ad hoc strategies for the distribution of alternative fuels in other modes of transport together with key sectoral and regional/local stakeholders. This would apply where the Regulation does not set mandatory requirements, but where emerging policy needs linked to the development of alternative fuel technologies should be considered.

4. Conclusion

The drafted regulation on the deployment of alternative fuels infrastructure depicted in this research seems to be a real avant-garde. First, due to its extremely ambitious environmental goals and a very tight timetable for their achievement. National policy frameworks covering the scope of the regulation have to be ready for implementation already in 2025. Secondly, because a regulation as a legal instrument is going to have far reaching implications for member states' legal obligations and their accountability before both domestic courts via direct effect principle and the Court of Justice of the EU for possible non-compliance. As for the moment of first reading of this draft in European Parliament, there is no will to soften its objectives. It is quite the opposite, the EP Committee on Transport and Tourism suggests the European Commission to closely monitor the fulfilment of the obligations of member states laid down in the Regulation, especially regarding the installation of publicly accessible charging and refuelling points across their territory. Moreover, to faster achieve the AFIR Reg.

ambitious objectives - states should be fined EUR 1000 for every charging station not installed (EP Committee on Transport and Tourism, Draft Report on AFIR Reg., p. 20).

On the other hand, regarding the EU environmental perspective, and its increased climate ambition for 2030 this new regulation will be a very promising development. It is very consistent, however going much forward, with the whole Fit-for-55 legislative package and following the direction in which the internal market develops. Member states estimate a rapid increase in sales of electric vehicles, albeit with very strong regional differences. Prospects suggest that there could be more than 7 million electric vehicles in 2025 and more than 30 million in 2030. While at the end of 2020 around 1.8 million electric vehicles were registered, many member states revised their ambition on targets and corresponding measures. For 2030, the estimates would represent an overall share of electric cars of around 15% of the total current car stock. However, at single member state level, planning and ambition for 2030 ranges from less than 1% to more than 40% of electric cars in the total car stock (COM/2021/103 final, p. 7). Considering the above mentioned forecast it would be advisable to reformulate some of the binding member states' obligations – just to guarantee their deployment of a minimum amount of recharging infrastructure at national level that equals a battery electric light-duty vehicle share of 2 % of the total projected light-duty vehicle fleet by the end of 2025, than 5 % of this fleet until the end of 2027, and 10 % by 31 December 2030 (EP Committee on Transport and Tourism, Draft Report on AFIR Reg., p. 31).

On balance, the pressing environmental problems involved in the production, transport and use of fossil fuels, the increasing energy demand, and the need for countries to improve energy security and reduce dependence on foreign energy sources are leading countries to promote the use of alternative fuels in the transport sector. Technological gaps and cost differences are becoming increasingly smaller, and it is only to be expected that alternative fuel vehicles (AFVs) will soon be very serious competitors of the conventional ones.

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Verification of Functional Safety Concept with System FMEA

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Abstract

In presented contribution we describe the preparation and realization of verification of the Functional Safety Concept (FSC) according to standard ISO 26262:2018, Functional safety – road vehicles. The functional safety concept (FSC) is a statement of the functionality to achieve the safety goals. FSC verification can be performed using the system FMEA (S-FMEA) method. This method allows the specification of the functional safety requirements, with associated information, their allocation to system elements within the item architecture, and their interaction necessary to achieve the safety goals. The selected software tool was software APIS IQ with Mechatronic FMEA extension. To comply with the safety goals, the functional safety concept based on System FMEA contains safety measures (including the safety mechanisms), to be implemented in the item's architectural elements and next specified in the functional safety requirements. The concept of FSC verification using the S-FMEA is demonstrated with the solution of S-FMEA for Electric Parking Brake (EPB). The FMEA model of EPB is based on the known standard VDA 305-100.

Keywords: functional safety, electric parking brake, FMEA, ISO 26262:2018, safety concept

JEL Classification: L740, L790, L630

1. Introduction

In our contribution we describe of preparation and concept of verification of the functional safety concept (FSC) according to standard ISO 26262:2018 [1]. The functional safety concept is a statement of the functionality to achieve the safety goals [2] [3] [4]. Its verification is performed using the System FMEA (S-FMEA) method. This method allows the specification of the functional safety requirements, with associated information, their allocation to system elements within the architecture, and their interaction necessary to achieve the safety goals. To comply with the safety goals, the functional safety concept based on System FMEA contains safety measures (including the safety mechanisms), to be implemented in the item's architectural elements and next specified in the functional safety requirements. The concept of FSC verification is based on S-FMEA and is demonstrated with the solution of S-FMEA for Electric Parking Brake (EPB) with software APIS IQ and its Mechatronic FMEA extension. The FMEA model of EPB is based on the known standard VDA 305-100 [5].

2. Problem formulation and methodology

2.1 Problem Formulation

To comply with the safety goals, the functional safety concept based on S-FMEA contains safety measures, including the safety mechanisms, to be implemented in the item's architectural elements and specified in the functional safety requirements. The concept of FSC verification using the S-FMEA is described with the reference solution of S-FMEA for Electric Parking Brake (EPB), which is based on the standard [6], [5].

2.2 Methodology

For each failure cause in S-FMEA model, related safety measures are specified. Two types of safety measures are possible:

- Detection measures: e. g. failsafe and monitoring functions. Failure detection action is taken to mean all actions that are suitable for detecting a potential failure when it occurs. In S-FMEA, these are trials, experiment and tests with subsequent analyses until release is achieved
- Avoidance safety measures: e. g. functional, technical, design specification, defined test or rare situations of exposure. These failure preventions (or failure reactions) are taken to mean all preventive actions that have been employed in the product/process design with the aim of avoiding failure causes or reducing their probability of occurrence. The S-FMEA takes account of introduced actions that prevent or minimize design failures; the process FMEA those that prevent or minimize process failures.

The traceability between the installed safety measures in the S-FMEA, e.g. failsafe and monitoring functions occurrence rating therefore allows the design quality of system at vehicle level to be evaluated.

2.3 Mechatronics FMEA

Our S-FMEA was created in APIS IQ software with Mechatronics FMEA extension. This extension of APIS IQ software is not an independent editor in the APIS IQ software, but an extended functionality in the failure nets created by APIS IQ in step 3. The mechatronics function can be in APIS IQ activated via the menu *Tools* | *Workstation Settings* | *Settings* by checking the checkbox Enable support for mechatronics FMEA on the General tab. The failure net can be extended by the following elements:

- Error detection
- Error reaction
- Operating condition

Error detections and error reactions are derived from functions. That means that functions are dragged by means of *Drag & Drop* (or by means of Special Drag) into a failure net and defined in there are error detection or error reaction. Error detections and error reactions are secretly created as objected subordinate to the function shortly after the operation was performed by the user. Error detection and error reactions have the same name as the function from which they are derived. Operating conditions can be generated directly in the failure net via the context menu. The purpose of the mechatronics FMEA is to be able to revaluate causations after they entered different operating conditions by means of error detections and error reactions and therefore lead to other or differently weighted effects.

3. Problem Solution

3.1 Required steps in safety measures analysis

In the following text we will show how the fulfilment of safety goals for a system with electric parking brake (EPB) [6]. We can show using a suitable system FMEA (S-FMEA) model for verification safety goals. To create S-FMEA model we used APIS IQ [7] as a world-wide acceptable software tool. In creation of verification FMEA model we will follow steps:

1. Structural analysis for vehicle system with EPB. At Figure 1 we can see a structure of EPB system. Failure effects (it is a FMEA term) are defined on Vehicle level, failure modes are located on brake assembly level and failure causes on components level leads to the failure modes on Brake Assembly level
2. Functional analysis and functional net for vehicle with EPB is followed after creation of structural analysis. Functions at Vehicle level represents all safety goals derived from hazard analysis and risk assessment (HARA). A set of functions at Brake Assembly level represents implemented functions in EPB. Functions at Component level represent implemented subfunctions in EPB components (we created them from VDA-305-100 standard [5]
3. Failure Analysis and failure net. Failures at vehicle level represents violations of safety goals. Failures at Brake Assembly level represents its failure modes. Failures at Components levels generate causes of failures at Brake Assembly and at the end violation of safety goals at Vehicle level. At Figure 2 is possible to see an example from APIS IQ software screen and explanation how failure causes generate failure effects on vehicle level which exact mean violation of safety goals.
4. Safety measures analysis with APIS IQ software. Safety measures analysis we performed by APIS IQ FMEA editor with its "Mechatronics FMEA" extension [7]. At Figure 3 to Figure 5 reader can see installed safety measures in system FMEA (see next chapter).

3.2 Description of safety measures and mechanism in S-FMEA built on APIS IQ software

3.2.1 Error detection functions and error detection

The creation of safety measures in the S-FMEA model in the APIS IQ environment requires a specific procedure, which we will describe in the following text. The Figure 3 represents a screenshot from APIS-IQ and describes error detection mechanism which was added to S-FMEA. On left upper part of figure (APIS IQ structure editor), for Brake Assembly two structures (elements) can be seen: at level 2 "2_Failure reactions" and at level 3 “3_Failure detections”. Both these APIS IQ elements represent installed safety mechanism in S-FMEA model. The structure “3_Failure detections” contains a set of error detection functions with corresponding error detection (see right upper of this figure). Both elements have the same description text – in this case we see error function “Clamping / release time monitoring” with corresponding error detection. Lower part of the image represents the bottom panel in APIS IQ. This bottom panel is synchronized with the top panel (structure editor); the bottom panel represents functional net editor. Here we see how the error function was connected by S-FMEA modeler to the functions and errors which are created in steps 1-3 (see previous chapter). All these APIS IQ elements are localized in the third (component) layer in structure editor.

3.2.2 Error detection functions and error detection

Until this time we showed at Figure 3 implementation of set of error detection functions and error detections in element “3_Failure Detections”. At Figure 4 we will study implementation of set of error response functions and error response in element “2_Failure Reactions” (see upper panel, structure editor, left side). On right side is possible to see a set of error response functions with error responses (both have same text description). At failure net editor in below panel is possible to see full net of safety mechanism. Right side of this panel represents “classic” parts of FMEA model (in sense of FMEA VDA standard). It is possible to see detection actions and preventive actions joined with each function and its associated failure. These elements are joined with created safety mechanisms on left side. Each error response function with corresponded error response is in this S-FMEA model connected direct to own safety goal or top function on vehicle level.

4. Conclusion

Our task was to prepare a functional safety concept (FSC) verification using a FMEA system. The functional safety concept (FSC) is a statement of the functionality of item to achieve the safety goals. We have shown the achievement of safety goals using the system FMEA (S-FMEA), which was preceded by safety analysis. We have described the individual steps of safety measures analysis. Subsequently, we described the safety measures and mechanism and expressed them with S-FMEA model built on APIS IQ software with its “Mechatronics FMEA” extension. In this software, we have added a detection mechanism and a safety mechanism to the FMEA model. By this step we connected them with safety goals and verified FSC by this way.

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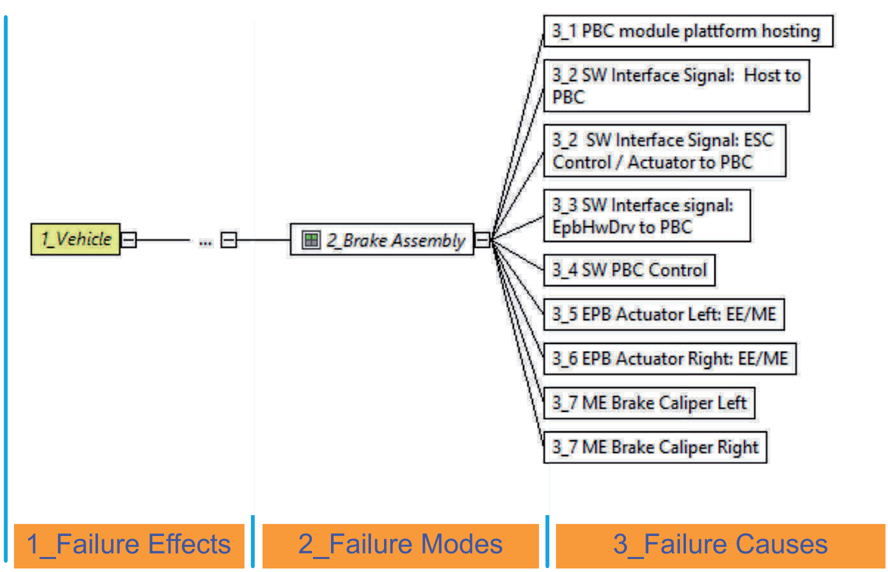
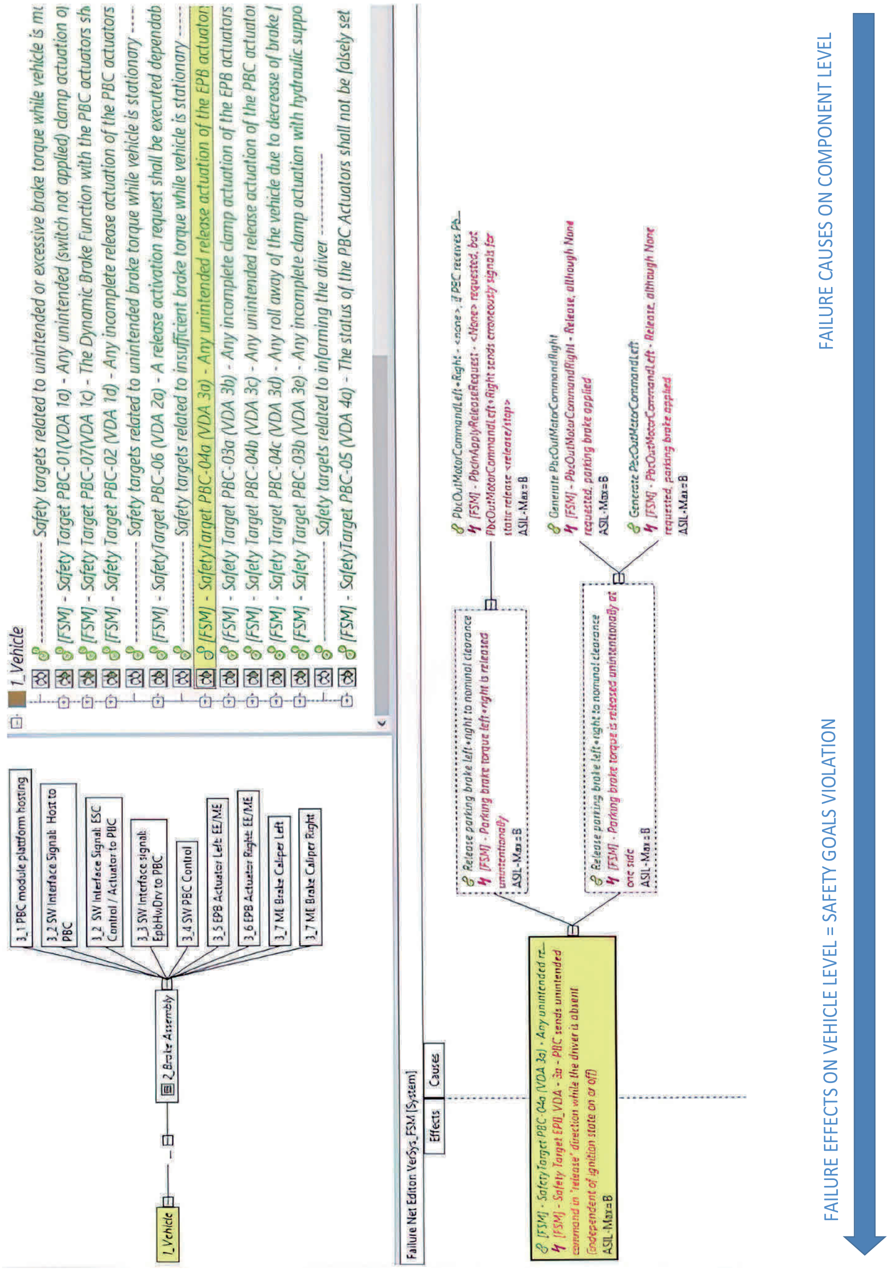
Figure 1: FMEA model, part „Structural analysis" of vehicle with electric parking brake



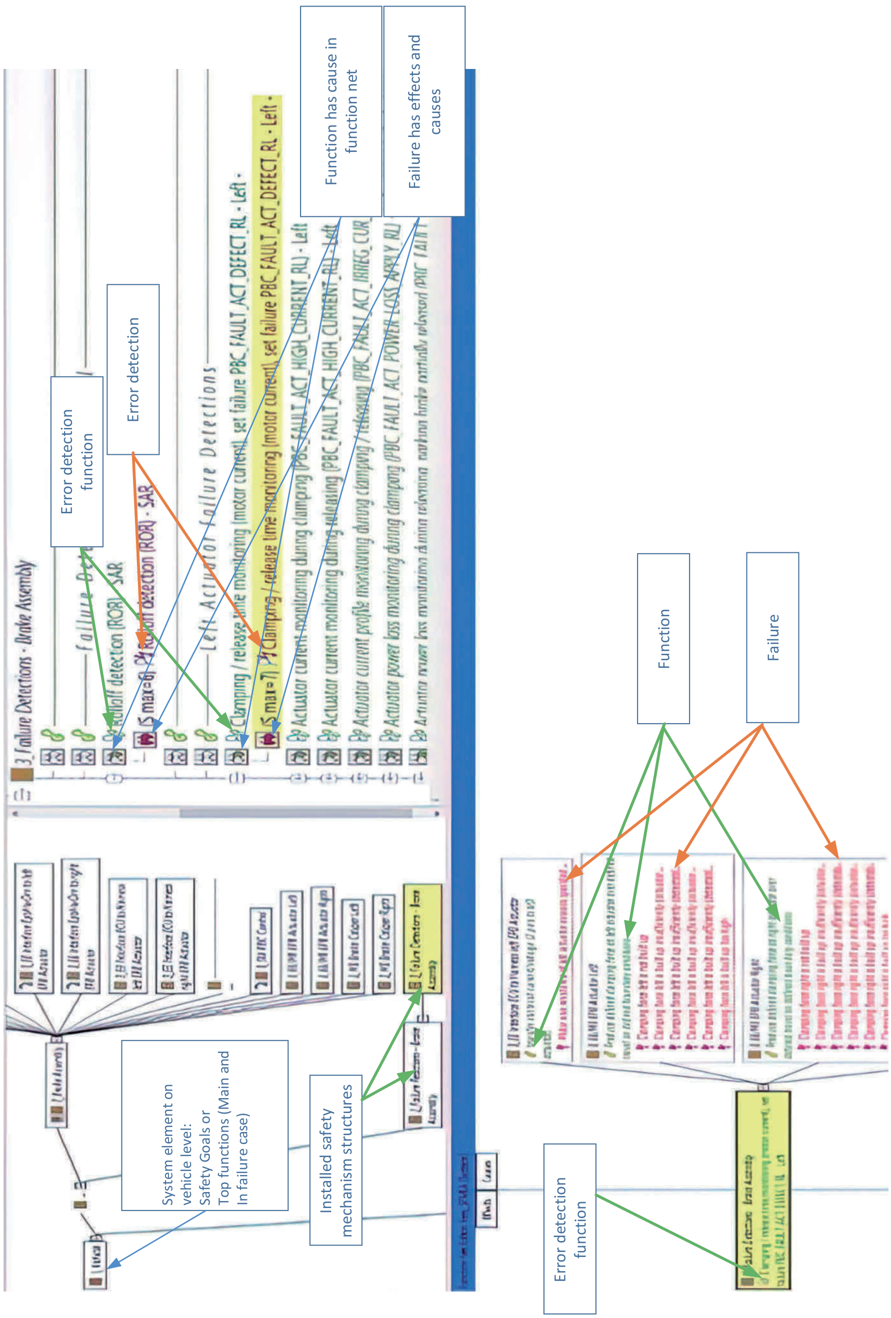
Source: excerpt from system FMEA created on information from VDA-305-100 standard, [5]

Figure 2 : An example from APIS IQ software screen and explanation how failure causes generate failure effects on vehicle level



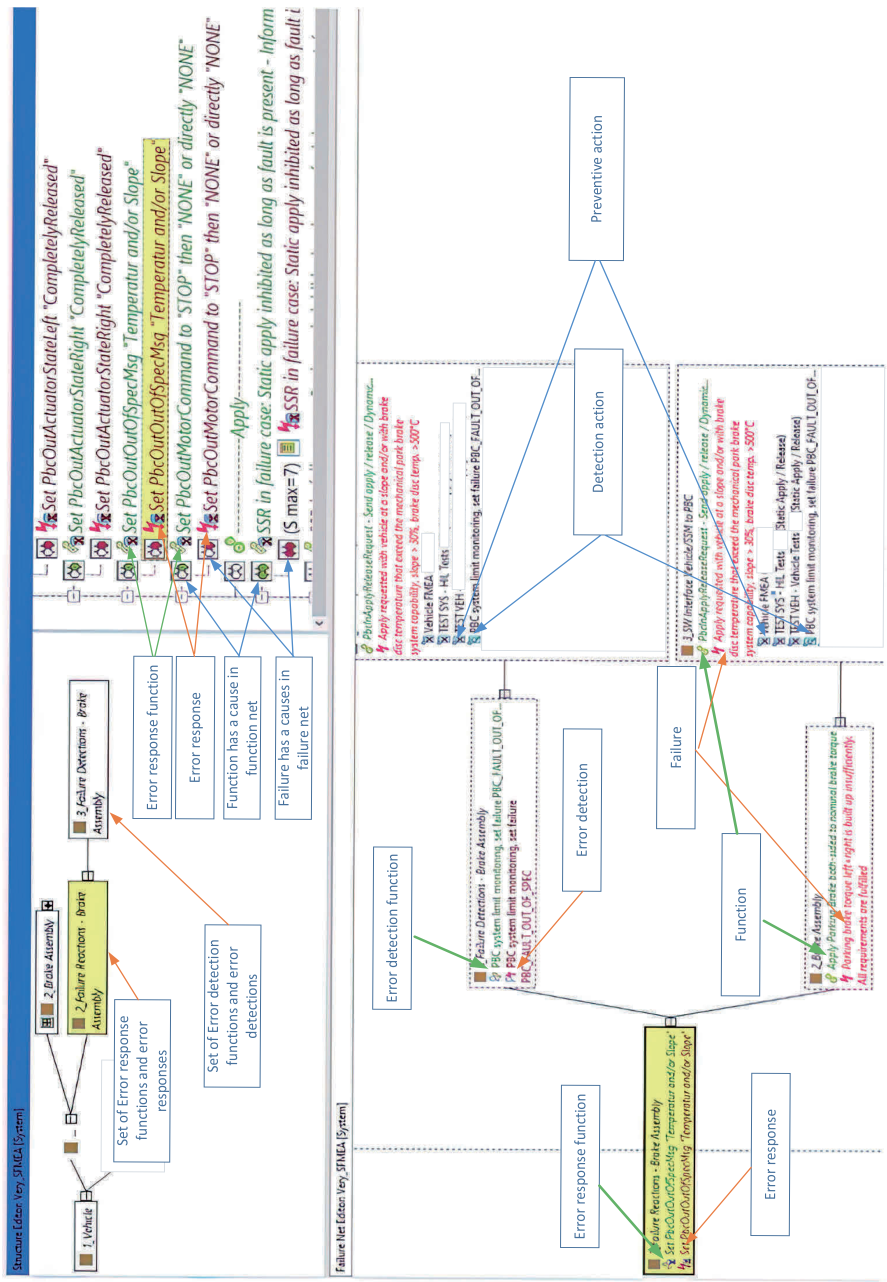
Source: excerpt from System FMEA created on information from VDA-305-100 standard, [5]

Figure 3: Installed safety measures in System FMEA – error detection



Source: excerpt from system FMEA based on standard VDA-305-100, [5]

Figure 4: Installed safety measures in System FMEA – Failure reaction



Source: excerpt from system FMEA based on standard VDA-305-100, [5]

Understanding automotive management issues by business simulation

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Abstract

The automotive industry goes through a major transformation in relation to new technologies, global competition by new players and changing markets, shortage of material, local regulations and worldwide trade barriers. These aspects increase the requirements for automotive managers. In order to prepare students for tasks in automotive management, serious games in forms of computer based business simulations did find their way to university education. Skoda Auto University uses the *StratSimManagement* simulation by *interpretive simulations*, HTW Dresden University of Applied Sciences uses *Auto Manufacturing* from *IndustryMasters*. Both business simulations games are compared and evaluated to the general and the current topics of the automotive industry. Both simulation games cover different aspects. Participants of the simulation games of both universities answered a questionnaire. The students feel much more involved in the simulation than in classical frontal teaching. 80% of the students think, that the simulations imitates the real business environment quite well, 75% feel well prepared for a job in the automotive business.

Keywords: business simulation, change management, strategic automotive management, serious games, teaching methods

JEL Classification: I230, L62, M0 www.aeaweb.org/jel/guide/jel.php

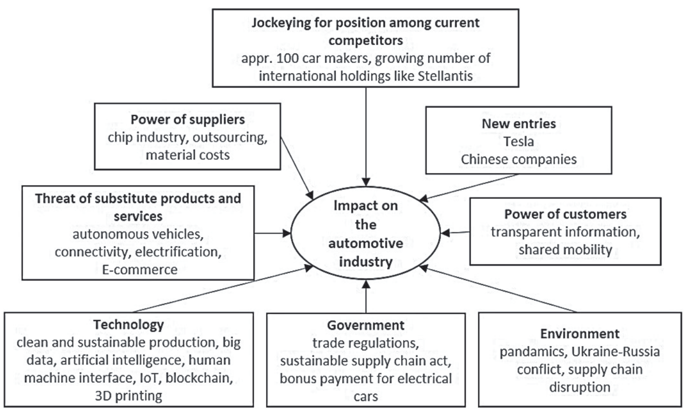
1. Introduction to Automotive Management and Business Simulation

1.1 Current Topics in the Automotive Industry

The automotive industry is challenging a major transformation. It is not just the change in field of the business, almost every topic is undergoing a change process. The new mobility concepts in the automotive industry are based on: electrified, autonomous, shared, connected and yearly updated cars (Kuhnert et al. 2018). The transformation effects all parts of the automotive supply chain. With new technologies and new driving concepts suppliers need new raw materials like Lithium for the battery production (Vitta S. 2021). Flexible, resilient and sustainable production will change the way of manufacturing the cars (VDA 2021). Marketing, sales and distribution will change due to E-commerce activities (Hagemann B. et al. 2021).

Porters *Five Forces* strategy tool (Porter 1979) is still a valid method to characterize the position of a company in an industry branch. Jockeying for position among current competitors is the daily business for automotive companies. The bargaining power of suppliers is still high due to high share of material costs. The chip shortage and the rivalry for this strategic product has come up in 2020 as a new challenge in the supplier relationship (Wu X. et al 2021). The treat of new entrants like Tesla (Milosheska 2012) or Chinese companies like Nio (Gusbeth 2021) enter the European and global market. With this new competitors new innovations for products and services came up (Santhakumar 2022). The power of buyers is constantly high, new mobility concepts like shared mobility effects the way, companies have to act with their customers (Buss 2020).

Figure 1: Currents impacts on the automotive industry



Source: own elaboration

Figure 1 summarizes the current impacts on the automotive industry.

In Germany the employment rate in manufacturing of direct employment in the automotive sector is 11.3%, in the Czech Republic even 13.7% (ACEA 2021). Compared to the average of the European Union of 8.6% (ACEA 2021), the automotive industry is in both countries an important employer. Therefore and due to the changes of the different impacts, the skill set of the car makers will shift (Hagemann B. et al. 2021). This has to be considered in the education of future employees.

1.2 Business Simulation as a Teaching Method

Computer simulation in teaching is one of the tools of so-called project teaching. At present, the project teaching method is gaining in importance. The complexity of the globalized world requires the choice of more dynamic methods of educating students at all levels of education, including the tertiary. In some cases, it is clear that classical frontal teaching methods may seem too static, not allowing such a degree of understanding of the interconnectedness of the world and the need for immediate application of theoretical knowledge to specific managerial decision-making. Project teaching is characterized in particular by the fact that for a certain, usually longer period of time, when selected complex problem is solved, requiring a higher degree of cooperation, coordination and combination of knowledge than in the case of frontal teaching. The project can then take the form of a question and a search for an answer to it, or it can be a challenge that always reflects the learning objectives of the subject.

The principles below reflect the usual project architecture:

- Identification and transfer of key knowledge in relation to the researched subject
- Achieving a higher level of skills in critical thinking, healthy communication, teamwork, team playing
- Development of self-management and time management
- Involvement of all students
- Emphasis on the applicability of the solution found
- Creation of conditions and environment for searching for relevant sources, data acquisition, their interpretation and subsequent use for the decision-making process and selection of the solution to the problem
- Bringing teaching closer to the real environment
- Changing the role of the teacher, accepting the position of coach or mentor
- Transfer of the launch initiative to the students
- Use of systems sciences
- Strong feedback during the evaluation of the adopted solution

An activating approach to acquiring students' knowledge and skills can be considered a major bonus of the above project teaching methods. The effective architecture of project teaching leads to a broader development of the student's skills, which he will use not only during the following studies, but especially after the beginning of his professional career. A side effect can be the attractiveness of study, arousing interest in the subject and refuting the often-presented opinion based on experience with the classical frontal method, that teaching is not very lively.

According to Tseng and Yeh (2019), the most difficult task is to intersect the three basic sets of knowledge needed to successfully master the simulation. These are the sets Contend knowledge, Technological knowledge, and pedagogical knowledge, where the intersection is the ability to implement content into technology, the ability to pass content through pedagogical procedures and finally the ability to use technology for the teaching process.

Numerous studies yield results that have one common denominator. A deeper understanding of the problem was identified, a longer-lasting ability to keep the acquired knowledge in mind, more suitable conditions for knowledge interaction and new knowledge creation, i.e. easier acquisition of application skills and the ability to combine knowledge from other subjects (Bauer, 2022, Project teaching, 2022). During the project teaching, there is also the development of presentation skills, the ability to formulate ideas and factually argue the results of the project, or in a discussion about the solution of partial steps. Project teaching thus brings the real world closer, concretizes the subject and can thus help to overcome the excessive abstractness of the issue and develop soft skills (Dömischová, 2011, Coffey, 2022, Buck Institute of Education, 2022).

The above is also confirmed by the research conducted by Chis et al. (2018) on a representative sample of 53 Irish university students. The comparison of learning outcomes in classical teaching and in project teaching using computer simulation showed an improvement of evaluation by 26.56% and only 1.9% of students were evaluated with less than 40% success rate, which represents more than a twofold reduction in study failure.

The teacher has more tools at his disposal during project teaching. He can develop the project independently, for example in the form of a case study. Or he can choose a computer program as the main teaching tool, while the current offer of teaching computer programs is wide. The advantages of this tool include a broader and more comprehensive coverage of the issues addressed, the opportunity to get closer to the real solution to problems. As a rule, the offered programs include the possibility to work both with the internal environment of the company, which students manage, but also the micro and macro environment of the company, which determines business activities. During the simulation, students can observe the mutual interaction of the elements of the company's system with the elements of its surroundings.

In terms of acquisition costs, it is possible to choose between granting a permanent license or to purchase a one-time license for the current simulation according to the number of students. The advantage of the first solution is the possibility to work in the off-line mode, the disadvantage is the higher acquisition costs. In the second case, it is necessary to ensure a quality Internet connection, as the simulation takes place online on the provider's servers. This type of license makes the cash flow better. Of course, the appropriate HW equipment is a prerequisite.

1.3 Selected Simulation games

The following text presents two computer simulations that are currently used in teaching at our cooperating universities, Dresden and Mladá Boleslav. The characteristics of the simulation SW are based on clarifying the philosophy of the game, the degree of complexity and the basic functionalities. It also includes the optimal time allowance and course structure.

1.3.1 StratSim Marketing

StratSim Marketing is a product made by American company Interpretive. Simulation SW is one of a number within the product portfolio of this company and was selected as the most suitable for teaching the subject Strategic Marketing Management. The main reason for choosing the product is the fact that the simulation is directly focused on the automotive industry.

Students make decisions in the areas of strategic management, product development, processes and operations, comprehensive marketing, financial management and accounting. Students divided into small teams simulate the TOP management of cars and compete for ten years in a highly competitive environment, as is the case in reality. The simulation is designed for advanced knowledge level and the prerequisite is the completion of basic courses in management, marketing, business economics, accounting, microeconomics and macroeconomics. The product is suitable for teaching in the master's degree. The simulation includes a standard market environment, of course with a certain degree of simplification. Students analyse data and information from both the immediate environment of their company and the general environment and also analyse the internal environment of the company for managerial decision-making, subjects, including mathematics in the usual managerial activities. The explicitly set goal is to increase (at least maintain) market share, share value, rating, value of the company's perception of customers, profitability indicators, further maintain an adequate level of indebtedness, expand the product portfolio, innovate existing products. Everything is designed for the level of creating strategic plans, ie for a longer horizon (Deighan et al., 2022, Jakubíková, 2013, Kotler, Keller, 2013)

During the simulation, the usual phenomena occur, such as a change in customer preferences, economic stagnation, fluctuations in fuel prices, rising labor prices, increased inflation, etc. These anomalies are then incorporated into medium and short-term plans to work with the product portfolio, modify pricing strategy, expand or narrow the structure of their distribution networks and, last but not least, adjust their marketing communications. Product portfolio management respects diversification in relation to the product life cycle (Jakubíková, 2013, Kotler, Keller, 2013, Krajcik, Blumenfeld, 2022).

StratSim simulation covers the following specific areas:

- Management of the technological profile of production and the level of production lines of the carmaker
- Management of the development centres for new cars and upgrades existing cars
- B2C and B2B market management
- Distribution network management
- Car production management and decision-making on expanding the factory's production capacity
- Complete financial management of the carmaker

They also have market and marketing research tools to test customer segments, designed car prototypes, market conditions, including advanced tools such as Perceptual Mapping and Conjoint Analysis.

Project teaching puts the teacher on a different level. The necessary preparation before starting the project seems essential (Dömischová, 2011, Coffey, 2022, Deighan et al., 2022). Emphasis is placed on clarifying the philosophy of simulation explaining the functionalities of the program. At the moment, the pedagogue changes into a coach, whose task is to lead students to the answers in a mutual discussion, how to implement a situational analysis of their company, how to evaluate the obtained data, how to incorporate them into strategic plans and how to refine them into operational plans. It is obvious that project teaching places higher demands on the teacher (Kratochvílová, 2006), the result is a deeper understanding of the subject taught by the student.

1.3.2 Auto Manufacturing Business Simulation

The Auto Manufacturing Business Simulation is part of the portfolio of digital business games of IndustryMasters GmbH https://www.industrymasters.de/. This digital business game is a cloud-based simulation. Different teams act like a complete automotive company and form a market. The teams play against each other and have to make decisions about research & development (R&D) activities, production, marketing, human resources (HR) and finance. It takes 20 quarters or five virtual years to go through on simulation cycle. The main goal is maximizing the share price of the company, the simulation calculates the share price and other financial data after each quarter. The players have to make the following decisions:

- R&D: investment in drive technology (electrification, autonomous and connective driving), development of cars/ product launching (type: product features; engine: combustion, hybrid, battery driven)
- Production: strategic decision of production capacity in Europe, USA and China
- Marketing: pricing policy, marketing activities and budget
- HR: hiring or laying of managers, salary planning and ensuring high motivation
- Finance: complete financial planning including investment plan, KPI for: profit and loss, balance-sheet, cash flow

The market environment is in addition changing from year to year. Typical changes are:

- New environmental regulations in term of CO_2 emissions
- Impact of CO_2 emission scandal
- New trade tariffs between USA and China
- Changed buyer preferences
- Governmental initiatives for low emission cars

The players have access to all different KPI, which are good visualized. The facilitator (moderator) of the game gets additional information after each quarter. A simulation briefing summarizes the actual situation in terms of: geographical markets, products, SWOT analysis, investment plan and main KPI's.

The complexity of the simulation game is quite high. The simulation game has an avatar, which gives the team different hints what they have to observe and offers the team direct recommendations. Also some decisions can be delegated to the simulation program, e.g. for human resources. This reduces the number of decisions which each team has to do.

1.3.3 Comparison of two introduced programs

Both simulation games have the same focus: increasing the share price of an automotive company in a competitive market. Derived from a strategic plan, the participating teams have to make decisions in different categories. Table 1 compares and summarizes the different games.

Table 1: Comparison of StratSim and Auto Manufacturing

		StratSim	Auto Manufacturing
1. Management Aspects	Strategic Management	yes (i.e. SWOT, PESTEL, Case studies)	yes (i.e. SWOT, Case studies)
	Risk Management	No, max. indirect	No, max indirect
	Quality Management	no	no
	Supplier Management	no	no
	Project Management	yes, intensive	yes, intensive
	Technology Management	yes (electrification and other aspects)	yes (electrification, auto. and connected driving and others)
2. Depart-ments	Production, Marketing, Human Resources, Finance, R&D	yes	yes
	Procurement	no	no
3. Market and Environment	Regulations	no	yes (CO_2 fine)
	Incentives	no	yes (for electrical cars)
	Supply Chain Disruptions	no	no
	Tariffs	yes (labour, trade)	yes (labour, trade)

Although the basis of the simulation games are the same, they differ in some aspects.

2. Problem Formulation and Methodology

The basic problem is to find out whether project teaching has a positive impact on students' knowledge and their ability to develop, combine and create new knowledge in comparison with classical frontal teaching, whether soft skills are developed during this teaching method and also whether project teaching helps in the transformation of theoretical knowledge into the application level in order to bring real practice closer.

Research questions

- Do students prefer project teaching in the form of simulation instead of frontal teaching?
- Is business simulation a tool that allows you to apply and combine knowledge gained from previous studies and transform the theoretical level of knowledge into practical?
- To what extent is the current situation of the automotive industry simulated?

For these purposes, the research method of questioning carried out through a questionnaire survey was chosen. The questionnaire contains a total of 15 questions, 14 of which are closed and 1 open with an offer of your own free expression of the project teaching method in the form of computer simulation. Closed questions are binary, scaled, with the choice of one variant, as well as questions involving the selection of variants with the option of choosing multiple variants.

A total of 50 respondents from the current teaching semester of both universities participated in the survey. To the research, several students was selected like that used in the case of the research of Chis et al. (2018). Intentional selection was chosen. All students in the year who completed the complete course participated. All answers obtained are valid.

2.1 Model and Data

The first two questions have a sorting character, while the first of them shows the structure of the respondent according to the university and the second verifies whether the respondent was confronted with project teaching in the form of computer simulation during the study.

Subjects with computer simulation. This question focuses on the structure of subjects in which the student encountered computer simulation. The results show that most often the student used computer simulation in subjects dealing with business management as General / strategic management, automotive management, marketing and also the area of logistics and supply chains. The following are subjects such as accounting, human resources management and banking, which are, however, represented by a minority.

Preference of the project teaching. The results clearly indicate a preference for project teaching through computer simulation. Only 8% of students would choose the classic frontal teaching method. Even more important is a detailed analysis of the answer to this question. Students could choose the *Definitely yes* and *Rather yes* option, with 50% of students clearly convinced of their choice and the remaining 42% would prefer the simulation.

Ability to organize in a team. A total of 54% of students clearly confirm that they learned during the simulation how to optimize the organization of work and communication in the team. Another 42% tend to agree with this statement. Only 4% of students do not feel that teamwork has taught them better work organization skills during the simulation.

Necessity of combining knowledge from several subjects. The architecture of complex business simulations of a strategic nature, by its very nature, forces the use of the entire portfolio of knowledge, their combination, and new knowledge is created here. This premise is confirmed by the results, when almost all respondents (96%) admitted that they had to incorporate knowledge gained in other subjects.

Increasing of the ability to transform theoretical knowledge into practical knowledge. The question of whether simulation can increase students' ability to transform theoretical knowledge into practical knowledge was again answered unequivocally. For 86% of students, it is a tool to find out how to apply the acquired theoretical knowledge in a practical business decision-making process. It is obvious that simulation has another function, namely the transposition of theoretical knowledge to the application level.

Increasing of the soft skills level. During the simulation, teamwork increased the level of soft skills in 86% of students. These include the development of communication skills, the ability to argue their solutions, the ability to coordinate, fulfil team roles, the ability to listen, be responsible for the whole, share success and failure in the team, self-management and time management, strengthening the entrepreneurial spirit.

Different involvement during simulation in comparison to frontal teaching. The intensity of students' involvement in teaching is one of the important determinants of learning. Active involvement significantly increases the ability to acquire and especially retain the transferred knowledge. The results show that for 94% of students, simulation is a form of teaching, thanks to which they are much more involved than in frontal teaching.

Degree of compliance simulation environment with real business environment. In order for simulation to have the desired effect for students, it is necessary to monitor the extent to which the simulation environment is close to the real world. It is clear from the essence of the matter that computer simulation cannot capture the diversity of real life and must abstract from many. Nevertheless, software developers must strive to mimic reality as much as possible. It is clear from the answers that both SWs are doing relatively well in this respect. A total of 30% of students consider the agreement to be unequivocally adequate and 58% of students favour "Rather yes".

Focus on the actual situation of the automotive industry. This question reflects students' views on whether the simulations used include current automotive challenges, such as electrical driven cars, autonomous and connective driving, creating of strategic partnerships, robotics and other current trends. In 84% of cases, students believe that simulations contain these issues and students are forced to solve them in the decision-making process.

Simulation as a tool for future job preparation in the automotive. An important aspect of the survey was to find out if students believe that using simulation in their teaching can help them prepare well for their future careers in the automotive industry. A total of 78% of students believe that this type of teaching contributes to the preparation for future careers. On the contrary, 14% of students answer that the simulation is rather unprepared and 8% of students are convinced that this tool is not beneficial in terms of preparation for future employment.

Identification of areas with earned skills. During the survey, attention was focused on the identification of areas, subjects in which students developed skills due to participation in the simulation. In 90% of cases, it is about improving project management and team management skills, with about three-quarters of students declaring improvements in marketing knowledge, supply chain management, planning and product development. Half of the students improved in innovation Management, for a third of the students participating in the simulation was a way to improve their skills in accounting and quality management.

Future internship or job in the automotive industry. The penultimate question aims to find out students' interest in combining their future work experience with the automotive industry. In the future, almost 84% of students from both universities would like to work in the automotive industry. The remaining 16% of students admit that they would rather choose their future workplace in another industry.

Further comments. The last question can be seen as a space for expressing other opinions and comments in relation to the use of simulation in teaching. The added comments are mostly positive, for some students the subject, in which simulation was used as a teaching method, was one of the best perceived subjects in the whole study. Students especially praise the experience gained and the development of their skills.

3. Problem Solution

The results of the research can be considered unambiguous and allow the answer to the research questions. Students definitely prefer project teaching in the form of computer simulation. This tool allows you to apply and combine previously acquired knowledge and transform the theoretical level of knowledge into the application level. Students also consider this form of teaching to be effective in preparing for their potential future employment in the automotive industry.

The results of the current survey are in full agreement with the results of the previous survey conducted in 2017 by co-author M. Beranek. Due to the fact that over the last four years, despite the Sars-Cov pandemic 19, students' attitudes towards project teaching have not changed, students declare that they benefit from this form of teaching, we can only recommend more massive implementation of this method in tertiary education.

The number of crisis and the speed of changes have accelerated the transformation of the automotive industry and generates a new skill set for automotive managers. The simulation games concentrate on four of the five forces of Porter's model: position among competitors, power of buyers, new entrants and threat of substitutes. The immense investment in new technologies is in different extents part of the simulations. Tools for different management tasks are as well integrated as changing business environments. What is not included in the games are supply chain/ procurement strategies (i.e. for chip shortage) or risk and crisis management (i.e. Sars-Cov pandemic or war in Ukraine).

4. Conclusion

Simulation games provide a valuable contribution to modern teaching-learning methodologies. Participants evaluated both used online simulation tools in a very positive way. Based on a good fundamental skill set in business administration and management, the simulation should take place at the end of the bachelor education or within a master course. Participants gain not only business expertise but also improve their soft skills. Most of the current topics of the automotive industry are depicted in the games. Increasing the complexity of the game can be done by adding different scenarios. Besides technological changes, crisis have a major impact on industry in 2022. Therefore risk and crisis management with different changing environments have to be integrated in the simulation games.

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Analysis of the Effect of Gearbox Design on Gear Meshing

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Abstract

The transmission is an integral part of every car and contributes to its operating efficiency and driving acoustics. The design and construction of the transmission must therefore keep in mind the basic requirements of trouble-free functionality, long service life, high efficiency, and low noise. In this context, the aim of this paper is to present some design elements of gearboxes that affect the gear mesh. This in turn affects the gear mesh of the gearing and its acoustics. The structural elements that affect the gear meshing are not always included in the design of the gear set. Therefore, the influence of the applied bearings and the effect of the shifting mechanism are analyzed in detail in this paper.

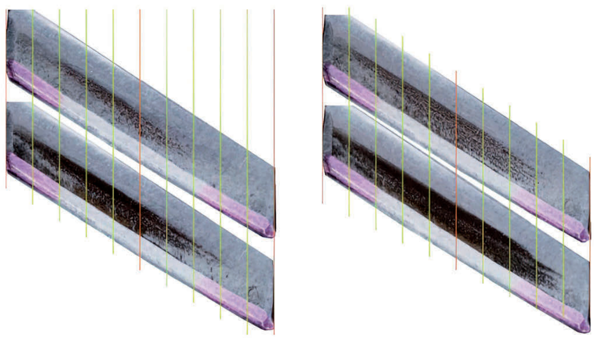
Keywords: gearbox, gear meshing, acoustics, bearings, shifting mechanism

JEL Classification: L74, Q55, R41

1. Introduction

The gear tooth contact pattern influences the pressure distribution during power transmission and transformation (Moravec, 2009). The contact pattern is the area of the tooth flank that is used during the real shot. It is therefore the area created by the mutual contact of the individual teeth during the mesh (Pavlík, 2020). We must distinguish the one path contact pattern when two specific teeth are engaged, i.e., one contact of two teeth during engagement (one tooth path) under specific load, speed and part temperature conditions. And then the total contact pattern, which can be defined as the contact pattern appearing on one tooth after contact with all teeth of the mating gear under constant conditions of load, speed, and temperature of the parts (sum of individual contacts), see Figure 1. The size of the contact pattern is then directly influenced by the size of the instantaneous actual contact ration coefficients ε_α and ε_β (and therefore ε_γ), which can be very different from the calculated ones, when only the ideal geometry of the gearing without any deformations and micro-corrections is considered, i.e., with mutual full contact of the teeth (Graf, 2017). Again, a distinction can be made between the actual contact ratio of two specific teeth and the actual contact ratio after mesh with all teeth (Pavlík, 2017). The contact pattern indicates the correctness of the gear mesh, and it is obvious that it would be ideal from the point of view of load capacity to be continuous over the entire tooth surface with smooth ramp-ups. Sudden sharp transitions cause step changes in the force effects in the gearing and consequently vibration and noise in the gearing, especially at the first harmonic tooth frequency. They can also induce stress concentration and thus create pitting.

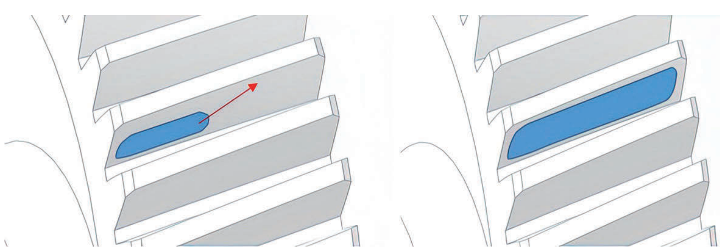
Figure 1: Examples of contact patterns, above are the one path contact patterns, below is the total contact patterns, on the left side of the figure the gear load is about 2 Nm and on the right side is 30 Nm



Source: Škoda Auto, a.s., internal materials

However, the contact pattern is altered by various changes in the effects exerted during operation on the gearbox containing the gears and on the gearing itself. These effects are mainly due to changes in operating torque load, operating temperature and input speed (Figure 2). These operational changes and their combination, also due to the variation of the engagement stiffness due to the changing engagement duration, induce changes in the deformation of the different parts, so that these deformations are not constant during operation (Lewicky, 2016). Gearbox housings deform, shafts deflect, gear racks bend, bearings deform. The teeth themselves bend and their surface deforms.

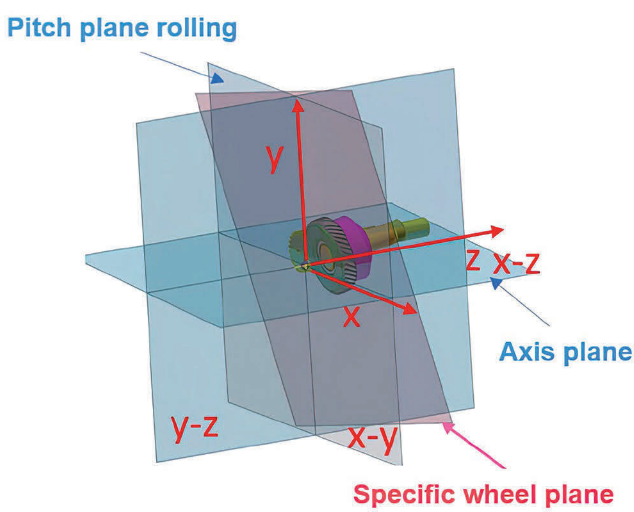
Figure 2: Example of a change in the contact pattern caused by different deformations of the parts, in this case caused by a change in the magnitude of the load (low load on the left, high load on the right)



Source: Škoda Auto, a.s., internal materials

In practice, all gearbox manufacturers try to reduce the impact of all the above-mentioned influences on the contact pattern (i.e. the load capacity of the gearing) by selecting various modifications of the gear usable flank surfaces. These modifications are in the micrometre units, and therefore, in gear manufacturing, this is one of the most precise manufacturing processes in mass production engineering.
However, there are other phenomena in the gearbox that change the contact pattern, such as bearing clearances. Whether shaft bearings or change gear bearings. This is the slope of the change gears at the stage when the gear is engaged, which transfers power from the engine to the drive train. These change gears are generally mounted on needle roller bearings with appropriate radial and axial clearance. At the time of power transfer through it, the change gear on the needle bearing relatively does not rotated compared to the shaft. The axial and radial clearance of the bearing due to the transmitted force causes a general spatial slope of the gear wheel (Figure 3), which in turn causes a change in the gear tooth contact pattern.

Figure 3: Display of the inclination planes of the change gear from the clearance on the needles



Source: Škoda Auto, a.s., internal materials

Similarly, the contact pattern is influenced by the clearance of the shaft bearings and their fit in the housing parts when load forces are applied. Specifically, how these structurally necessary radial and axial clearances of the change gear and shaft bearings affect the contact pattern was examined in more detail.

2. Problem formulation, methodology approach to problem analysis

The aim of the research was to identify the sizes of the gear tooth contact patterns that are influenced by the behaviour of structural components such as bearings and gear shifting mechanism.

Two methods were used to determine the influence of the engagement area. The first method is the experimental imprint method in a real gearbox, which is based on the abrasion of a gear marking compound coating applied on the both tooth flanks. This method was accompanied by the second method by the theoretical calculation apparatus Multi-body System (MBS), which was used to calculate the deformation and stress distribution of the parts due to the action of other bodies by calculating on a model tuned by experimental measurements. The MBS model was then used to determine the degree of influence from the observed factor, whereby effects that cannot always be eliminated in reality can be easily suppressed in the simulation. Furthermore, the MBS method can be conveniently used to quickly determine the degree of influence of the factor under study, where conducting an experiment would be time and cost consuming due to the production of accurate part dimensions.

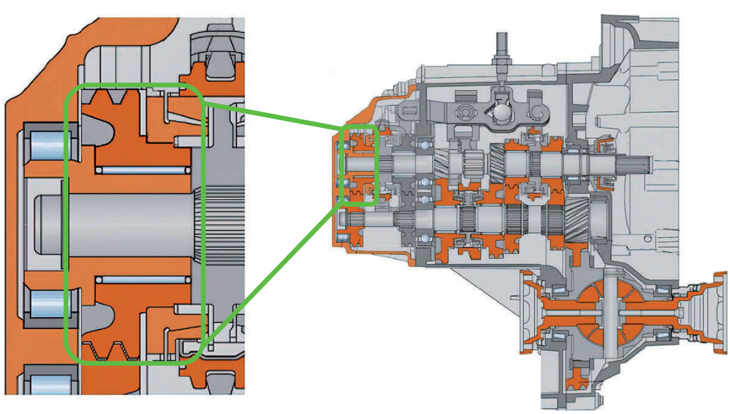
3. Solution procedure

In the process of assessing the size of the contact pattern, the gearbox design was analyzed and structural arrangements that could affect the contact pattern were identified. Analysis of the effect of the change gear fit on the needle bearings, shaft fit, sliding sleeve and needle bearing rolling element bodies were performed.

3.1 Effect of the change gear on needle roller bearings (radial clearance, axial clearance)

This factor has been experimentally investigated on the MQ200 gearbox on a sixth speed gear, where the drive gear wheel is mounted on needle bearings with a radial clearance of about 0.01 to 0.05 mm and an axial clearance of about 0.2 to 0.3 mm (Figure 4).

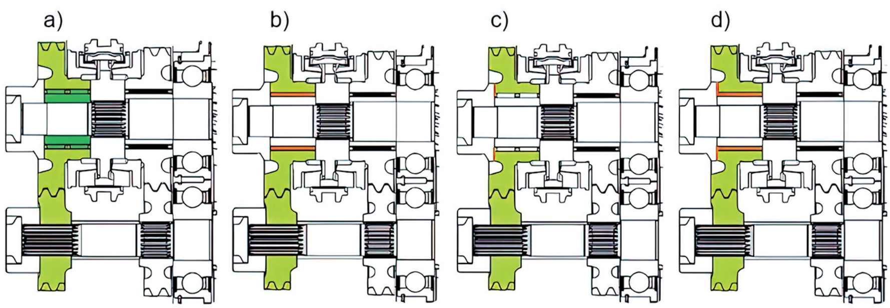
Figure 4: Schematic arrangement of the examined gearbox and its sixth gear



Source: Škoda Auto, a.s., internal materials

In the experiment, a gearbox with a radial clearance of 0.036 mm and axial clearance of 0.28 mm was used, which correspond to the above ranges. A progression was made from the serial produced gearbox with a change gear mounted on needle bearing (Figure 5a), to only the radial clearance adjustment by replacing the needle bearing with a sleeve without radial clearance (Figure 5b). Next, only the axial clearance adjustment using thrust washers (Figure 5c), to finally both clearances adjustment on the gear (Figure 5d).

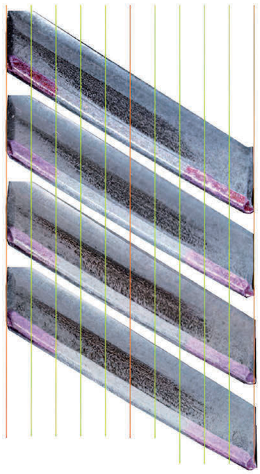
Figure 5: a) Serial produced gearbox, change gear mounted with radial and axial clearance on needle bearing b) Gear radial clearance adjusted, needle bearing replaced by precise sleeve c) Gear axial clearance adjusted with a precision thrust ring/washer d) Gear radial and axial clearance adjusted – combination of both adjustments



Source: Škoda Auto, a.s., internal materials

From the experiment performed at a load of 30 Nm, when comparing the contact pattern (Figure 6), it was found that the radial clearance adjustment affected (shifted and, due to microgeometry, increased) the contact pattern in the magnitude of 10% of the tooth width. The same effect was also produced by the axial clearance adjustment. Adjustment of both clearances simultaneously did not cause any further significant change in the contact pattern. Assessment of the change in the size of the contact pattern was made by dividing the tooth width into ten bands, as shown in Figure 6.

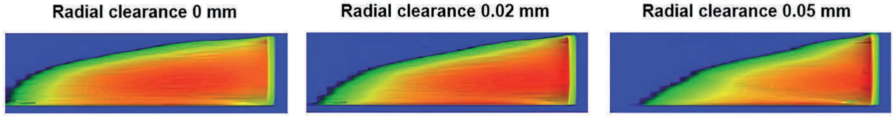
Figure 6: Contact pattern in each phase of the experiment



Source: Škoda Auto, a.s., internal materials

From this can be concluded that a radial clearance of 0.036 mm and an axial clearance of 0.28 mm in this gearing will reduce the contact pattern approximately by 10%. This can cause a reduction in gear life in real operation. MBS simulation calculations were also performed, where the influence of the radial clearance of the needle bearing on the contact pattern was monitored, while maintaining all other boundary conditions of the calculation. The simulation result for three choices of radial clearances of size (0 mm, 0.02 mm, and 0.05 mm) confirms the conclusions obtained from the experiment. The contact pattern tends to decrease with increasing radial clearance (Figure 7).

Figure 7: Effect of radial clearance of the needle roller bearing on the contact pattern

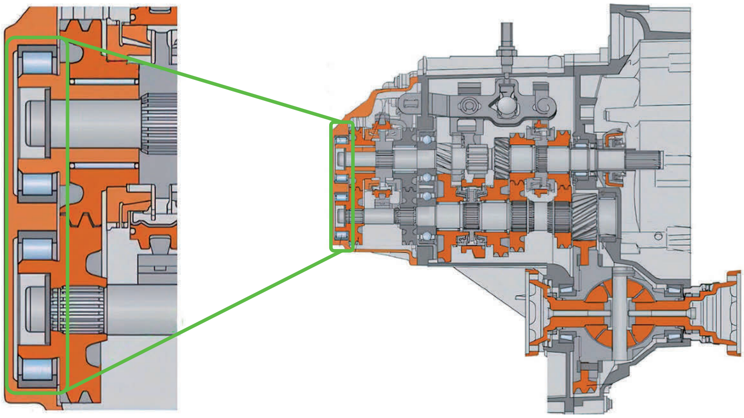


Source: Škoda Auto, a.s., internal materials

3.2 Effect of radial clearance of the shaft bearing (radial clearance of the shaft bearings in the cover)

This factor was again investigated on the MQ200 gearbox, this time on the fit of the shafts in the roller bearings in the gearbox cover (Figure 8). A model was developed to determine the contact pattern, which was verified by a real experiment. The input conditions for validation were identical clearances of the individual parts of the system (change gear and shaft fit clearances), identical load torque level and speed.

Figure 8: Schematic arrangement of the tested gearbox and marking of the tested bearings



Source: Škoda Auto, a.s., internal materials

Comparison of the contact patterns obtained in the experiment with the MBS simulation shows very good agreement (Figure 9). This makes it possible to assess the effect of radial clearance on the load carrying zone using only a simulation calculation method with sufficient accuracy and certainty of the correctness of the results.

Figure 9: Comparison of real contact pattern with MBS simulation

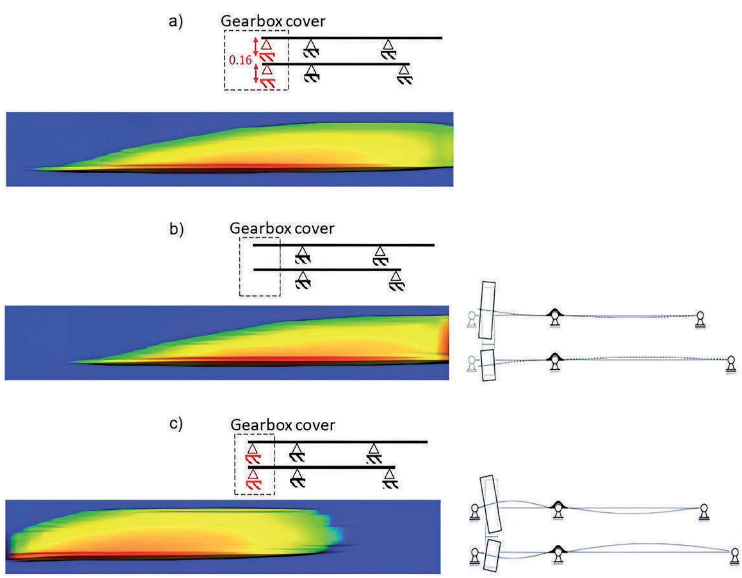
Source: Škoda Auto, a.s., internal materials

The effect of the radial clearance of the bearings was then simulated in the calculation in three steps, always at a load of 30 Nm. First step: arrangement with real radial clearances of both cylindrical roller bearings 0.16 mm (Figure 10a). Second step:

arrangement of both shafts without bearings in the cover (Figure 10b). Third step: Simulation of both shaft bearings with zero radial clearance (Figure 10c).

The figures (Figures. 10a; 10b; 10c) show the results of the contact simulation. The degree of its influence from the bearing radial clearances between the bearing inner ring, the rolling element and the bearing outer ring can be traced. In particular, the greatest influence is seen between the fixed and loose bearing and the bearing without clearance. Between a loose bearing and a real bearing with clearance of 0,16 mm, the effect can also be observed, but is not as pronounced. From the simulation (Figure 10b) – where a shaft deflection of 0.08 mm was found at a load of 30 Nm, it can be derived by logical deduction that the influence of the contact pattern from the cylindrical roller bearing with a radial clearance of 0.16 mm will only occur in this case at loads from 30 Nm upwards. Or, at 30 Nm, the clearances in the bearings will be adjusted to zero and the bearing will continue to serve as a supporting functional member. By clearance adjustment occurs the different relative position (slope) of the wheels (Figure 10b and 10c).

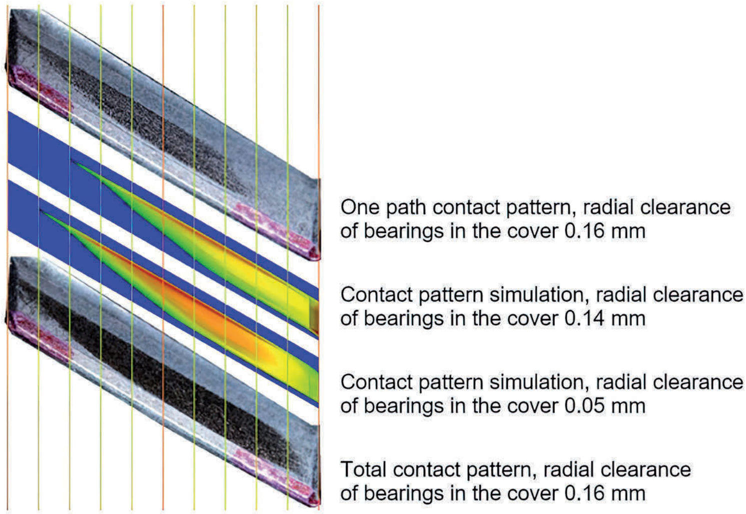
Figure 10: Contact pattern simulation a) real cylindrical roller shaft bearings in the cover with a radial clearance of 0.16 mm b) outboard mounted shafts without cylindrical roller bearings in the cover, shaft deflection 0.08 mm c) cylindrical roller shaft bearings in the cover without radial clearance



Source: Škoda Auto, a.s., internal materials

However, in an experiment to prove the behaviour estimation from the MBS calculation, it was found that the agreement between simulation and experiment was not sufficient with respect to the different shaft bearing clearances. (Figure 11).

Figure 11: Comparison of simulated theoretical and measured contact pattern



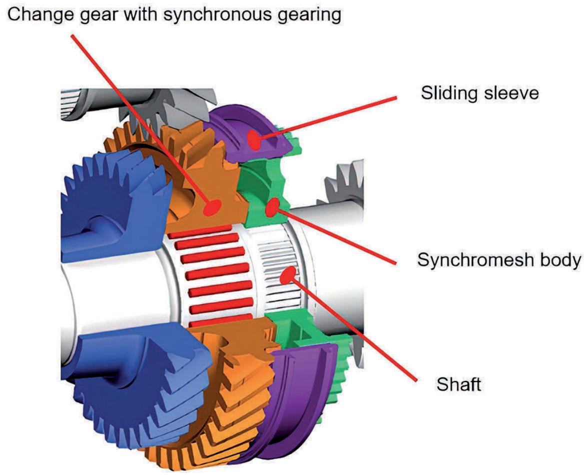
Source: Škoda Auto, a.s., internal materials

After checking the whole model and the properties of the individual parts, it was found, that there must be other factors in the chain affecting the contact pattern that influence the behaviour (slope) of the gearing. The element that was not considered in the model was the sliding sleeve and its engagement with the synchronisation gearing of the change gear. This observation led to the verification of the influence of the sleeve and its force action on the change gear.

3.3 Effect of radial clearance of the sliding sleeve

The sliding sleeve, when interlocked into the change gear, is the member that transmits the torque from the shaft through the synchromesh body to the change gear mounted on needle bearing. (Figure 12). Due to radial run-out, distortion, clearance, and manufacturing defects of the individual members in the design chain (shaft, core, sleeve, synchronous gearing), the slope of the change gear on the needle bearing is likely to be affected.

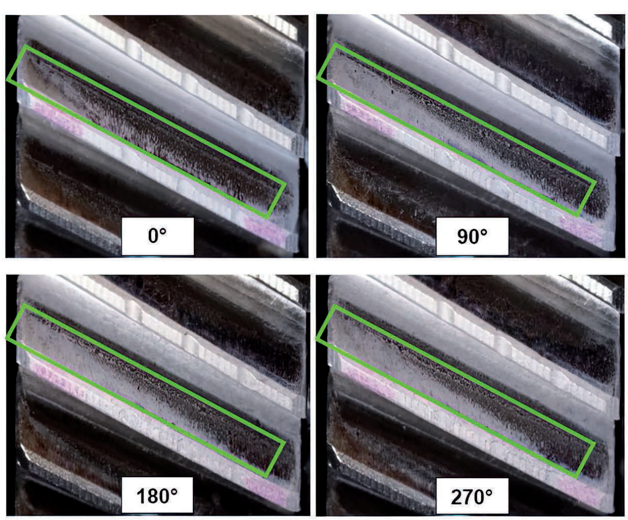
Figure 12: Interlocked sliding sleeve in change gear



Source: Škoda Auto, a.s., internal materials

The fact that the effect does occur was verified by an experiment on the contact pattern at the load of 80 Nm. The sleeve was always interlocked, the contact pattern measured, then disengaged, rotated by 90°, interlocked again and the contact pattern measured again. This was done 4 times, always with a by 90°. The contact pattern was evaluated as one path contact pattern, i.e., between the same specific teeth all the time. It was found that for a load level of 80 Nm the contact pattern is affected. (Figure 13).

Figure 13: Contact pattern at different positions of the sleeve, from top left: sleeve in position 0°, 90°, 180°, 270°



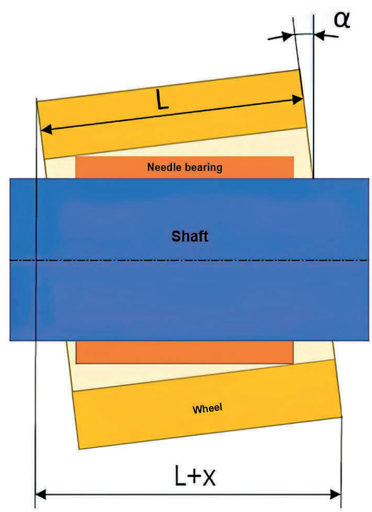
Source: Škoda Auto, a.s., internal materials

The degree of influence of the contact pattern is clearly visible from the figure between the 0° and 90° sleeve positions. The difference between the 90°, 180° and 270° sleeve angular positions is not significant. Exactly what caused this phenomenon (whether deviations in the spacing of the synchronous gearing, clearance between the sliding sleeve and the synchromesh body, misalignment of the synchromesh body on the shaft, or something else) is the subject of further research.

3.4 Effect of rolling elements (needles) of the needle bearing

Another factor that could affect the size, position and shape of the contact pattern is the needle bearings on which the change gears are usually mounted (Figure 14). Needle diameter tolerances, along with shaft and change gear diameter tolerances, together form a chain that determines the amount of radial clearance. In fact, the length of the needle is a factor that will also affect the potential amount of change gear slope. Its length is always less than the length of the bearing cage, which is considered as the design width of the needle bearing. However, the functional length is smaller and it is the length of the needle. The shape of the edge, or the size of the radius of the needle end, is also an important factor for change gear slope.

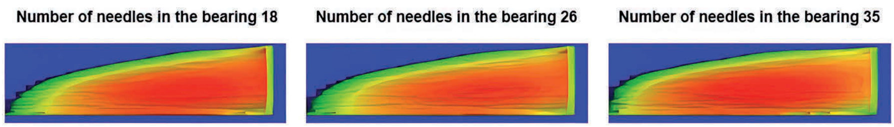
Figure 14: Schematic representation of the effect of the needle on change gear slope



Source: Škoda Auto, a.s., internal materials

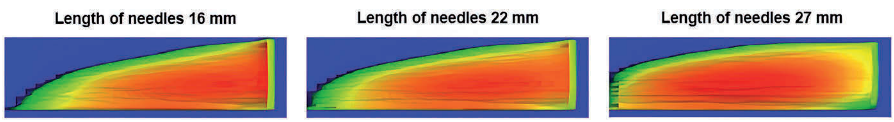
The exact extent of the influence of the shape, length, orientation, and number of needles on the contact ratios in the gearing is currently not fully mapped and will be subject to further verification. However, it is already apparent that the internal design of the needle bearing affects the contact pattern. As the number of needles in a bearing of the same geometric dimensions increases, the bearing bandwidth increases (Figure 15). And as the length of the needles in the bearing increases, while maintaining the number of needles, the bearing band also increases (Figure 16).

Figure 15: Effect of the number of needles in a bearing of the same dimensions on the contact pattern



Source: Škoda Auto, a.s., internal materials

Figure 16: Effect of the needle length of a bearing of different dimensions on the contact pattern



Source: Škoda Auto, a.s., internal materials

4. Conclusion

This article summarized several design influences that directly affect the gear tooth contact pattern, either one path or total contact patterns. The analysis of these influences was performed using two methods. The assessment of the contact pattern was carried out using an experimental method that utilizes the imprint of the teeth by abrasion of the gear marking compound coating applied on the both tooth flanks. Simultaneously, simulation calculations were performed using MBS, which can be advantageously used in future gearing designs if sufficiently verified by experiment. The research confirmed that the clearances in the needle bearings on which the change gears are mounted affect the size of the gear tooth contact pattern. Also, the number and size of the needles of these bearings contribute to changes in the size of these contact patterns. The contact pattern is also affected by the fit clearances in the shaft supports on which the change gear is mounted. The last element that has been investigated is the sliding sleeve, which also contributes to changes in the size of the contact pattern. This research is only seemingly unrelated to the effect of gearing strength or gearing acoustics. In fact, the change in the contact pattern affects the pressure distribution and thus the strength and life of the gearing. Similarly, a change in the contact pattern also affects the excitation of vibrations during tooth engagement and therefore the noise level of the gearbox. The research findings show that the influence of all substructures and their precision on the gear meshing ratios should always be considered and examined when designing or changing the design of any gear transmission.

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Gear life prediction based on load spectrum

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Abstract

This article describes the methodology of measuring the load spectrum (torques and speeds) when driving a car on different types of routes. Subsequently, it describes their processing using schematics to obtain the equivalent torque or degree of damage. The last part describes the gear life prediction based on the character of different travel routes.

Keywords: degree of damage, equivalent torque, lifetime, load spectrum, schematisation

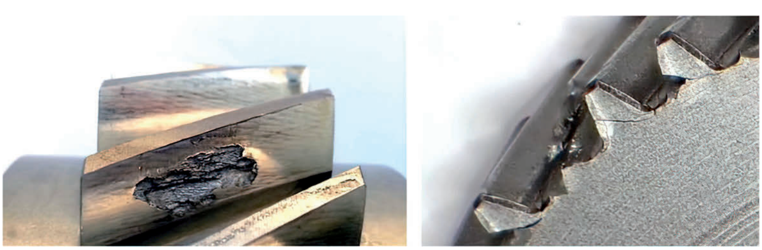
JEL Classification: C8, O3

1. Introduction

Any machine component that is stressed with variable loads has the potential to be damaged over time by fatigue failure. Whether the equipment will be damaged during its period of operation or for how long, is influenced by many parameters. On the component side, this is mainly determined by the shape of the component (Brumercik, 2020) (Gramblička, 2020) and its material properties (Hohn, 2003) (Hong, 2021). On the load side, the magnitude and frequency of variable load actions are decisive.

Gears are mainly exposed to two types of possible fatigue failures (Fig. 1), namely damage resulting from contact (Weresa, 2015) and from bending (Ličková, 2021). It should be noted that another serious way of damaging the gears can be caused by abrasion (jamming), which, however, does not display a fatigued character and, therefore, the following procedure cannot be used for such a prediction of gearings.

Figure 1: Typical tooth damage caused by contact (on the left) and by bending (on the right)



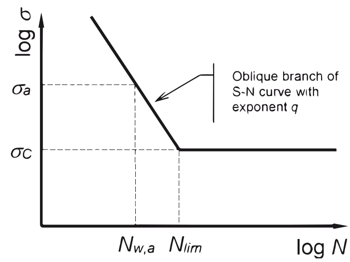
Source: own elaboration (2022)

In addition to the above-stated parameters, knowledge of the S-N curve with its characteristic for a given component is essential, or at least we must know the relevant exponent q for this curve's oblique branch if the gearing is stressed above the fatigue limit.

The oblique branch of the S-N curve can be defined using two points, the intersection of fatigue limit σ_C and the relevant limit number of cycles until the damage N_{lim} occurs, and some other point defined by the general load amplitude s_a and the corresponding number of cycles until the damage $N_{w,a}$ occurs.

For this oblique branch, the following basic relation applies (relationship 1). By rearranging this equation, it is possible to obtain the oblique branch exponent from the well-known S-N curve (relationship 2).

Figure 2: Theoretical S-N curve



Source: own elaboration (2022)

As the determination of the curve exponent is costly and time-consuming, the values stated in the literature are used. For the following predication, we start from (ČSN 01 4686) which is used for gears in car gearboxes (structural alloy steel, cemented and hardened, and stainless for structural steel, normalized annealed or heat-treated steel; carbonitrided) the following values are given:

- to calculate contact $q_{H,ČSN} = 10$,
- to calculate bending $q_{F,ČSN} = 9$.

$$\sigma_a^q \cdot N_{w,a} = \sigma_C^q \cdot N_{lim} = const. \tag{1}$$

$$q = \frac{\log N_{lim} - \log N_{w,a}}{\log \sigma_a - \log \sigma_c} \tag{2}$$

Since the standard (ČSN 01 4686), in Part 2, provides a procedure for calculating the equivalent force from the load spectrum

$$F_{H,e} = \sqrt[\frac{q_H}{2}]{\frac{\sum_{i=1}^{N}\left(F_i^{\frac{q_H}{2}} \cdot N_i\right)}{\sum N_i}} \tag{3}$$

$$F_{F,e} = \sqrt[q_F]{\frac{\sum_{i=1}^{N}\left(F_i^{q_F} \cdot N_i\right)}{\sum N_i}} \tag{4}$$

then following S-N curve exponents were used to calculate the equivalent moments:

- for calculation in contact $q_H = 5$,
- for calculation in bend $q_F = 9$.

Relationships (3) and (4) can be used to calculate the equivalent load for any load parameter – torque, force or tension.

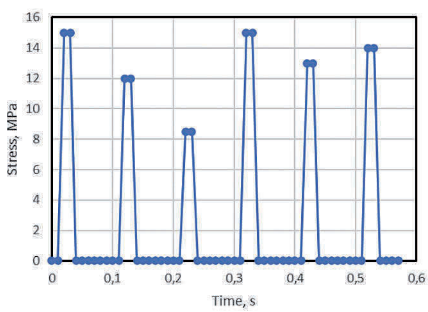
2. Problem Formulation and Methodology

2.1 Prediction of lifetime

If we move within the area of timed strength, the calculation is carried out using two possible procedures:

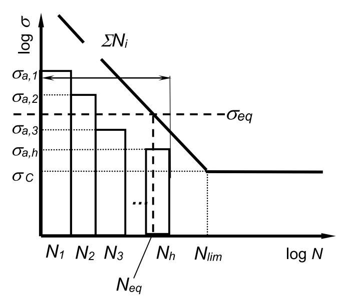
- **degree of damage** – each load change causes a certain stress amplitude s_a in the component, and each of these amplitudes causes some degree of damage to the part. The total degree of damage is the sum of these sub-degrees and the damage to the component occurs if the total degree of damage reaches the value of 1. This procedure is not used for gearing.
- **equivalent load** – this procedure is used to predict the lifetime of bearings and gears because the load on the tooth is repeated (if it is not an inserted wheel). Figure 3 shows an example of a load acting on one tooth of a gearwheel at 10 RPS.

Figure 3: Typical tooth load course



Source: own elaboration (2022)

Figure 4: Equivalent stress



Source: own elaboration (2022)

Equivalent load σ_{eq} is a load which on one level with the same number of cycles Σ_{Ni} causes the same damage as the load spectrum (Fig. 4). Mathematically, this principle is described by the following equation (5). After rearranging this equation, the calculation of the equivalent load (here equivalent stress) is done following the equation (6).

$$\sigma_{eq} \cdot \sum_{i=1}^{h} N_i = \sum_{i=1}^{h} \left(N_i \cdot \sigma_{a_i}^{q}\right) \tag{5}$$

$$\sigma_{\text{eq}} = \sqrt[q]{\frac{\sum_{i=1}^{h}\left(N_i \cdot \sigma_{a_i}^{q}\right)}{\sum_{i=1}^{h} N_i}} \tag{6}$$

where σ_{ai} are partial load values from schematization (Fig. 5),
N_i are the schematized numbers of these amplitudes.

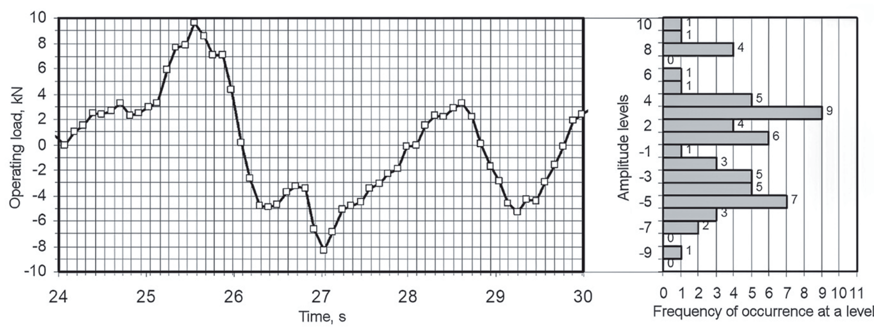
To calculate the equivalent load using the measured data (the load spectrum), two procedures can be used in principle:

- use each measured data taken for the load together with an adequate number of cycles (usually this is the number of gear revolutions during the sampling period). Following this procedure is simpler, however, it can be taken for only one data record,

- spread the measured load range into the selected number of levels and provide schematization into these levels. Following this method, this procedure is somewhat more laborious, but it will allow us to create partial schematizations provided for different periods, for example, in our case, for partial car routes taken under different conditions (in town, on a motorway…). Subsequently, it will allow us to combine these sub-routes and re-calculate one equivalent load value for the selected route combination. It will also make it possible to evaluate and compare the damaging effects of sub-entries. The following text describes the procedure following this point.

The principle of schematization for the force record is shown in a simple example in Figure 5. In the first step, it is necessary to determine the total scope of the record, which is here ranging from +9.6 kN to -8.1 kN. Therefore, the total range for the schematization was chosen as ±10 kN and 20 moment levels, as in this case, one layer has a range of 1 kN. The next, schematization is performed by determining the number of occurrences of a sample recorded in each level (for example, on the range of (level) 2.000 … 2.999 kN, 9 occurrences of measured samples were found).

Figure 5: The principle of level schematization



Source: own elaboration (2022)

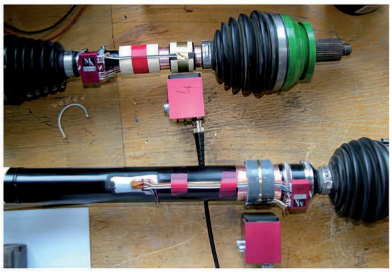
3. Problem Solution

The above procedures can be used only if we know the real load spectrum, i.e., the actual load on the component from the actual (or simulated) operation of the given machine. Therefore, an experiment was carried out in which the load spectra of a passenger car drive system were determined.

3.1 Obtaining a load spectrum

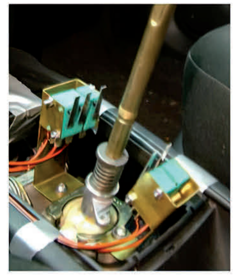
A Škoda Fabia 1.4 TDi 55 kW passenger car was used for the measurements. On the driving half-shafts, strain-gauge torque sensors were installed together with antennas for contactless signal transmission produced by the company ESA Messtechnik (Fig. 6). This system also included a magnetic sensing of the revolution of the current wheels. At the same time, micro switches were mounted on the gear lever, which made it possible to record the currently engaged gear (Fig. 7).

Figure 6: Sensing moments and revolutions



Source: own elaboration (2022)

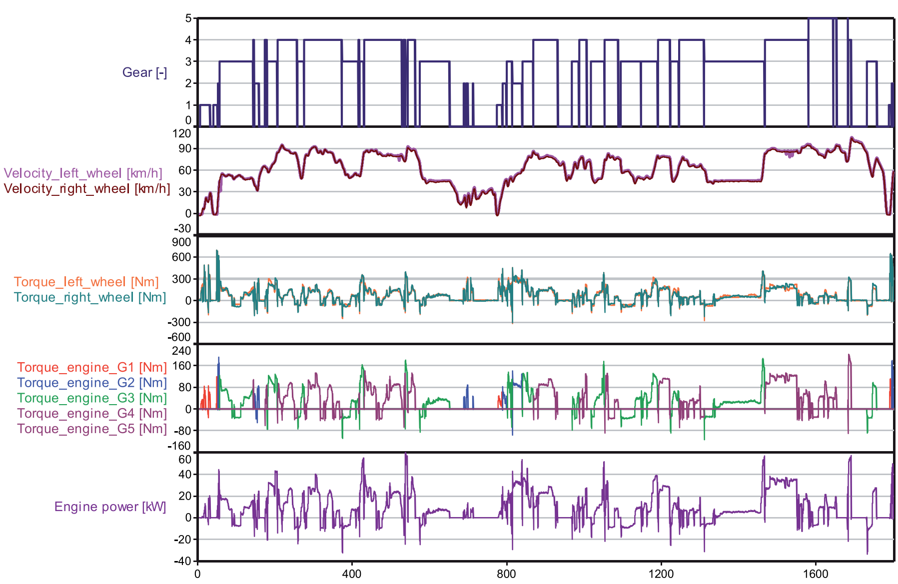
Figure 7: Engaged gear



Source: own elaboration (2022)

After mounting the sensors on the vehicle and putting the entire measuring chains into operation, a number of rides were made, which have been characterized as urban traffic, out-of-town journeys on the B-roads, and motorway driving. A typical record for driving on B-roads outside the town is shown in the following graph (Fig. 8). Gear engaged, torque in the wheels and driving speeds were measured, other data were calculated.

Figure 8: Measured data – example of a route part



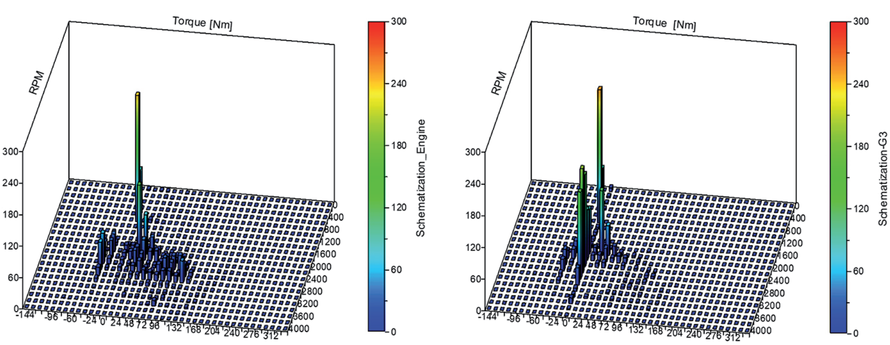
Source: own elaboration (2022)

3.2 Schematisation

The measured torque progress was schematized using two-parameter schematization – torque on the input shaft and engine speed (= gearwheels revolutions) following the procedure:

a) In the first step, it was necessary to determine the maximum and minimum values of moments and revolutions, and then the number and setting of levels were selected, for which the schematization will be carried out. 41 levels were selected, with the centre of one level being zero.
b) Subsequently, the histogram for these levels was calculated, with the fact that it was first the number of recorded samples falling into the respective torque-speed combinations.
c) Since the records were sampled with the same time sample, it was possible to convert this table from the number of samples to the number of shaft revolutions.
d) Such schemes were carried out separately for each gear, for the input and output from the gearbox (here it was necessary to change the torque and speed levels). This data is displayed more clearly in the following bar charts (Fig. 9), for the examples with torque moment from the engine (on the left) and for the moment of engaging the third gear (on the right).
e) In the next step, it was possible to add up all the numbers of revolutions for each torque moment and thus obtain the resulting number of revolutions of the shaft or relevant gearwheel for each torque moment level. This resulting schematization was quantified as absolute (that is, the number of revolutions for a given level) or as relative, where frequency means the relative ("percentage") share of the entire journey and the sum of the frequency is 1 (Figure 10).

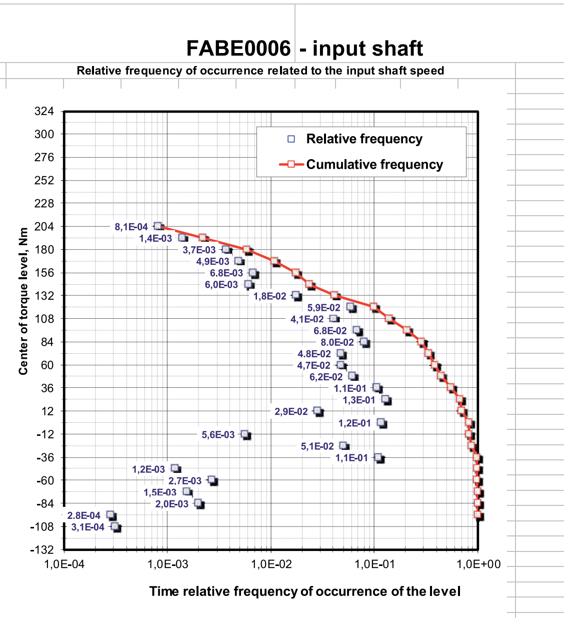
Figure 9: 3D illustration of two-parameter schematization



Source: own elaboration (2022)

Figure 10: Relative and cumulative numbers of load cycles

The center of the torque level	Relative frequency	Cumulative frequency
Nm	-	-
336	0,000E+00	0,000E+00
324	0,000E+00	0,000E+00
312	0,000E+00	0,000E+00
300	0,000E+00	0,000E+00
288	0,000E+00	0,000E+00
276	0,000E+00	0,000E+00
264	0,000E+00	0,000E+00
252	0,000E+00	0,000E+00
240	0,000E+00	0,000E+00
228	0,000E+00	0,000E+00
216	0,000E+00	0,000E+00
204	8,123E-04	8,123E-04
192	1,391E-03	2,203E-03
180	3,678E-03	5,882E-03
168	4,916E-03	1,080E-02
156	6,752E-03	1,755E-02
144	6,029E-03	2,358E-02
132	1,767E-02	4,125E-02
120	5,880E-02	1,000E-01
108	4,069E-02	1,407E-01
96	6,786E-02	2,086E-01
84	7,951E-02	2,881E-01
72	4,767E-02	3,358E-01
60	4,712E-02	3,829E-01
48	6,196E-02	4,449E-01
36	1,060E-01	5,508E-01
24	1,291E-01	6,799E-01
12	2,852E-02	7,085E-01
0	1,173E-01	8,258E-01
-12	5,610E-03	8,314E-01
-24	5,095E-02	8,823E-01
-36	1,097E-01	9,920E-01
-48	1,189E-03	9,932E-01
-60	2,683E-03	9,959E-01
-72	1,534E-03	9,974E-01
-84	2,006E-03	9,994E-01
-96	2,824E-04	9,997E-01
-108	3,085E-04	1,000E+00
-120	0,000E+00	1,000E+00
-132	0,000E+00	1,000E+00
-144	0,000E+00	1,000E+00



Total number of engine revolutions per ride	63 216,6	=	100,0%	
of which with gear engaged	55 801,6	=	88,27%	
For the towing side	44 787,2	=	70,85%	
and for the reverse side	11 014,4	=	17,42%	
Average speed during gear	39,9	1/s =	2393,4	RPM

Source: own elaboration (2022)

A summary statistical table (Table 1) then supplemented each schematization.

Table 1: Summary gear load statistics for the gearbox

Total travel time on the measured section	**1787,82**	**s**	**=**	**29,80**	**min =**	**100,0%**	**Total number of engine revolutions per ride**	**63216,6**	**=**	**100,0%**
of which 1st gear	28,56	s	=	0,48	min =	1,6%	of which 1st gear	625,2	=	1,0%
2nd gear	57,15	s	=	0,95	min =	3,2%	2nd gear	2607,9	=	4,1%
3rd gear	635,57	s	=	10,59	min =	35,6%	3rd gear	24590,5	=	38,9%
4th gear	594,50	s	=	9,91	min =	33,3%	4th gear	25206,4	=	39,9%
5th gear	71,39	s	=	1,19	min =	4,0%	5th gear	2574,3	=	4,1%
without gear engaged	400,64	s	=	6,68	min =	22,4%	without gear engaged	7612,2	=	12,0%
Drive side of tooth engaged	**1111,91**	**s**	**=**	**18,53**	**min =**	**62,2%**	**Drive side of tooth engaged**	**44599,9**	**=**	**70,6%**
of which 1st gear	28,16	s	=	0,47	min =	1,6%	of which 1st gear	611,7	=	1,0%
2nd gear	55,53	s	=	0,93	min =	3,1%	2nd gear	2541,5	=	4,0%
3rd gear	479,40	s	=	7,99	min =	26,8%	3rd gear	18349,1	=	29,0%
4th gear	497,94	s	=	8,30	min =	27,9%	4th gear	21277,1	=	33,7%
5th gear	50,87	s	=	0,85	min =	2,8%	5th gear	1820,5	=	2,9%
Backward side of tooth engaged	**275,26**	**s**	**=**	**4,59**	**min =**	**15,4%**	**Backward side of tooth engaged**	**11004,5**	**=**	**17,4%**
of which 1st gear	0,41	s	=	0,01	min =	0,0%	of which 1st gear	13,5	=	0,0%
2nd gear	1,62	s	=	0,03	min =	0,1%	2nd gear	66,4	=	0,1%
3rd gear	156,17	s	=	2,60	min =	8,7%	3rd gear	6241,4	=	9,9%
4th gear	96,56	s	=	1,61	min =	5,4%	4th gear	3929,3	=	6,2%
5th gear	20,52	s	=	0,34	min =	1,1%	5th gear	753,8	=	1,2%

Source: own elaboration (2022)

3.3 Equivalent load

For each journey made, it is possible to calculate the equivalent load according to the equation (6) modified to torque, i.e.:

$$T_{\mathrm{eq}} = \sqrt[q]{\frac{\sum_{i=1}^{h}\left(n_i \cdot T_i^q\right)}{\sum_{i=1}^{h} N_i}} \tag{7}$$

where T_i are the centres of the schematization levels (Fig. 10 first column),

n_i are partial relative numbers of shaft rotations (Fig. 10 second column).

Due to the use of relative values for the number of revolutions in the equation (7), there is the expression $\sum^{h}_{i=1} = 1$. When quantifying the example in Fig. 10, it is:

- for exponent $q_G = 3$ (bearing) is $T_{eq,G} = 75.94$ Nm,
- for exponent $q_H = 5$ (contact) is $T_{eq,H} = 92.52$ Nm,
- for exponent $q_F = 9$ (bend) is $T_{eq,F} = 114.71$ Nm.

3.4 The principle of recalculation the lifetime according to equivalent load

The given values of the equivalent moment can then be used to calculate the service life of gears from a given load spectrum, where each gear has a different torque calculation value for contact inspection and another for bending.

If the calculation is made from combinations of different measured routes, it is necessary to:

- select or find a suitable combination of these routes, for example, 50 % of motorways, 30 % B-roads and 20 % in town,
- reduce the frequency (see Table 2 column 2) for individual schematizations by the indicated percentage and then add up the route frequencies,
- from the schematization obtained that way, relevant equivalent moments must be calculated.

4. Conclusion

The above data show that for the gear lifetime as well as for other parts of cars (and not only cars), where there is considerable stochastic (random) load, it is necessary to know the actual load spectrum for optimization as best as possible, to avoid inadequate dimensioning of these parts.

Using the maximum torque moment of the drive for these calculations is completely inappropriate. Compare the maximum torque T_{max}, which is in the record approx. 200 Nm to the calculated equivalent values according to paragraph 3.3. In this context, it should be noted that the service lifetime of the parts is exponentially dependent on the load due to the exponent of the S-N curve. For example, when changing the calculation load using the above-stated example, it is from $T_{max} = 200$ Nm to $T_{eq,H} = 92.52$ Nm, it means an increase Δ of a calculated lifetime:

$$\Delta = \frac{L_{eq,H}}{L_{max}} = \frac{T_{max}^{q}}{T_{eq,H}^{q}} = \left(\frac{T_{max}}{T_{eq,H}}\right)^{q} = \left(\frac{200}{92{,}52}\right)^{5} = 47.2 \tag{8}$$

Unfortunately, the scope of this article does not allow closer analysis of the issue, according to which it is possible, for example, to make designs for reduced overload tests.

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Automotive GVCs in Czechia and Hungary – a comparative analysis

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Abstract

Czechia and Hungary are two economies, highly specialized in automotive production and engaged in automotive global value chains (GVCs) to a great extent. The main players in the two economies' automotive industries are mainly foreign-owned: OEMs and suppliers mainly from Germany, although there are locally owned or controlled firms as well. In this paper, we analyzed and compare the backward linkages in the automotive GVCs of the two countries. We describe, what is the role of foreign OEMs and suppliers and domestic companies, and how these roles relate to each other? What is the role of OEMs in shaping these linkages? We rely on a combined methodology. First, we analyze the input-output matrixes in order to present the local and international links of the automotive industry and to estimate, in which activities local suppliers play an important role and from which countries the various inputs come. We supplement this quantitative analysis with a qualitative one: based on company interviews. According to our results, local linkages are different in the two countries, with low presence of locally owned companies in Hungary. However, industry averages conceal large differences between foreign-owned and local companies. Upgrading is present, though it is rather slow. Increasing R&D activities are mainly driven by foreign-owned firms, though even some local Czech suppliers have R&D units.

Keywords: automotive industry, backward linkages, Czechia, Hungary

JEL Classification: F21, F69, L62, F63

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1. Introduction

The automotive industry belongs amongst the most fragmented industries (de Backer and Miroudot, 2013). Since the 1990s the changing geography of automotive production to less developed countries also included the post-communist Central European states (Sturgeon, van Biesebroeck and Gereffi, 2008). This was mainly driven by company strategies, characteristics of the respective countries and public policies (Humphrey et al., 2000). Pavlínek (2012) also stresses low production costs, geographic proximity to core markets and integration into the EU leading to lower economic and political risks and easing the flows of goods.

As the automotive production networks are highly hierarchical and thus vertically disintegrated, there are strong backward linkages between lead firms (auto producers) and large number of their component suppliers (Humphrey and Memedovic, 2003). This leads to highly asymmetrical power relations and quasi hierarchical or captive governance types within GVCs (Humphrey and Schmitz, 2002). Typically, tier one (or sometimes modular suppliers called 0.5 suppliers) produce complex products such as sophisticated parts of engines, brakes or door. Tier two suppliers produce other parts of engines or lights based on the designs provided by assemblers or 0.5/first-tier suppliers. Third-tier suppliers provide basic components such as car bodies or interior parts (Dicken, 2015), although supplier can produce a wide variety of products.

High level of integration of Czechia and Hungary into mainly European and German automotive GVCs through FDI realised by foreign multinationals is documented by various studies (Domanski and Lung, 2009; Pavlínek et al., 2017; Kordalska and Olczyk, 2019; Klein et al., 2021) This is also obvious from changes in the product compostition of exports from the Visegrad countries (Myant ,2018). However, this integration remained peripheral, no complete value chains were transferred to CEE, just certain, mainly labour-intensive processes (Pavlínek et al., 2017), benefitting mainly from low labour costs, while the most advanced activities remain in higher-wage countries (Krzywdzinski, 2017, Grodzicki and Skrzypek, 2020). Indeed, based on occupation-level data, the CEE economies remain specialised in production activities, which limits the domestic value added content of exports (Pellényi, 2020). Local content originating from locally owned or controlled suppliers has remained relatively low (Pavlínek et al., 2017), though company-level (Kazainé, 2013) and macro-level (Sass-Szalavetz, 2013) analysis point to some upgrading over time. While the CEE economies took a very similar development path, there are certain differences between their performance and upgrading (Pavlínek, 2021).

2. Problem Formulation and Methodology

In this paper, we analyse and compare the backward linkages in the automotive GVCs of the two countries, highly integrated in automotive global value chains. We describe, what is the role of foreign OEMs and suppliers and domestic companies, how these roles relate to each other? What is the role of OEMs in shaping these linkages?

Our paper relies on a combined methodology. First, through the analysis of UIBE (WIOD) data, we present the local and international backward links of the Czech and Hungarian automotive industry and estimate, where (in which activities) local suppliers play an important role and from which countries the various inputs used by the industry come.

Second, we supplement the results of the above analysis with information gained from company and expert interviews. In these interviews, we try to assess and identify the various factors, which influence the choice of inputs (local or foreign, and if foreign, from which country sources), and we list the most important factors influencing the extent of reliance on local suppliers by multinational firms. Among others, we conducted interviews with successful local suppliers and based on these sources of information as well as information from buyer firms, we determine the characteristics of successful local suppliers. In both countries, ten companies can be found in the interviewed sample. We supplemented the information gained from the company interviews with information from publicly available sources (newspaper articles, websites of the firms and balance sheets of the companies).

These two different methodological approaches supplement each other well and help us to overcome the well-known data problems and the problem originating from the lack of qualitative data on automotive lead firms and suppliers.

3. Problem Solution

3.1 Results of the data analysis

In the structure of production (Figure 1), the main difference between the two countries is the strong local embeddedness of the Czech automotive industry – around 40% of the total output is the contribution of various Czech industries in terms of intermediate consumption –, while in Hungary the domestic background links fell from 30 to 10% and imports represent 60–70%. However, even in Czechia import gradually increased while a small but rising domestic portion emerged in Hungary. It was one of our most important tasks to investigate the source and meaning of the 'domestic' rise, which has been revealed by background research and interviews.

Figure 1: The production structures of the automotive industries

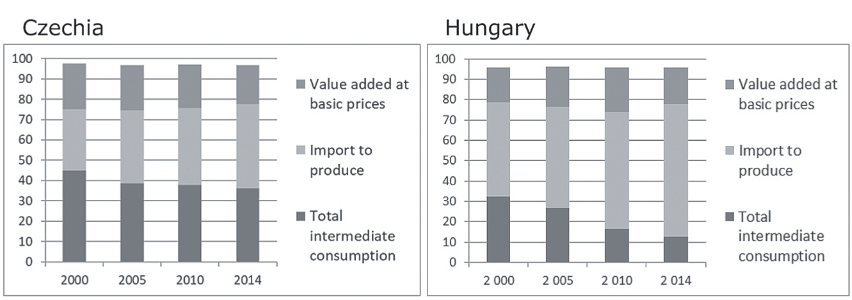
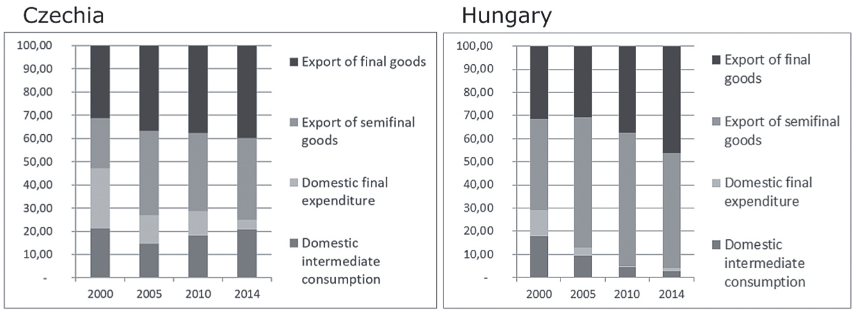


Figure 2: The expenditure structures of the automotive industries



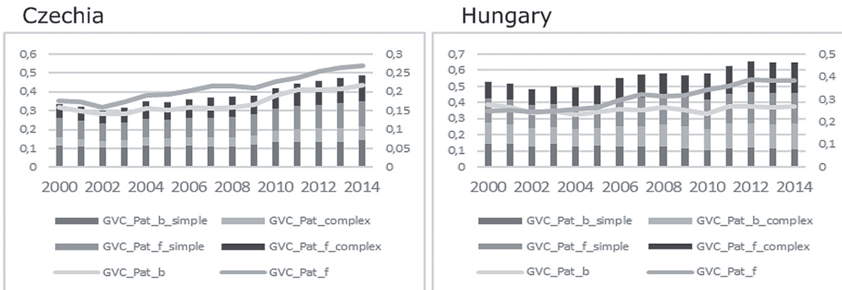
Source: own calculation and elaboration by UIBE

The expenditure structure of the automotive industries also profoundly differ. While in 2000 70% of the production was exported in Hungary, the Czech structure was more even: a bit more than 50% was exported, while the other half was domestically sold either as a final or a semi-final product. It is also different that the Czech automotive industry exported mainly final products, the Hungarian production system supplied mainly components to foreign partners. These structures partly melted: Czechia experienced a greater shift by drastically shrinking domestic final expenditure and rising ratio of semi-final goods export. In Hungary there is also a drastic fall in the local production, while the final product export was extended with dropping local intermediate production.

When comparing the participation ratios and production lengths as well as positions of the two countries, Hungary is more involved in the global networks, mainly by forward links, while the Czech automotive industry connections got more intensive both backward and forward. Though we found that the Czech industry is much more domestically oriented than Hungary, both countries have a forward participation dominance. Since participation is measured by the imported (backward) and the domestic (forward) value added contents of global export, this fact again draws the attention to the real ownership structure of the domestic production (discussed later).

In terms of the complexity structure of the links, simple value chain relations are relatively high, mainly in Czechia, which shows a more concentrated structure in space. Complex value chains are in both directions higher in Hungary, though the forward complex participation dominates the production process. While the Czech automotive industry had strong backward simple relations, later the complexity of its global value chain structure increased. In international comparison the Hungarian participation appears to be even more intensive, while Czechia takes place in the middle of the global range.

Figure 3: The change and the structure of backward and forward participation



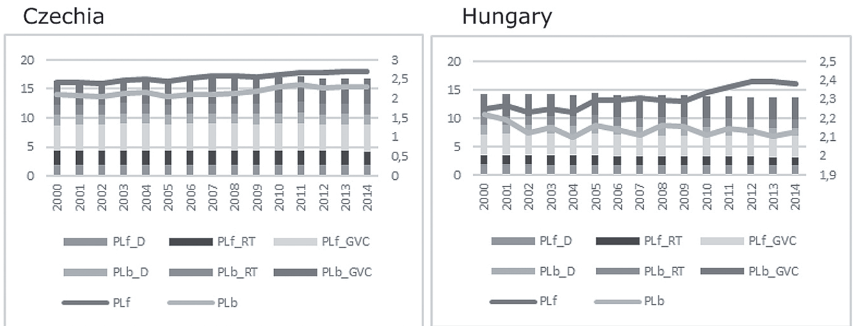
Note: Pat_b = backward participation; Pat_f = forward participation; simple = semi-final product crossing the border only one time and used by the importer for final expenditure; complex = semi-final product crossing border more than one time either as a re-export that returns or as an export that gets for final use in a third country. The left axis measures the GVC elements, the right one reflects the overall (GVC_pat) lines.

Source: own elaboration by UIBE

The global value chain length measures the average number of production phases weighted by the relative value-added contribution, from primary inputs to final products. By the nature of the activity the whole process contains domestic chains plus simple and complex value stages as well as the traditional trade of the final product. Since we differentiate the above types and parts, we can make conclusions to the position of the automotive industries of the two countries, too.

Our figures indicate that the length of the motor vehicle international production is longer as well as more even and stable in Czechia. In Hungary the backward part shrunk, it has a volatile nature while the forward part of the length extended. As a consequence, the Hungarian automotive industry shifted towards upstream position. The Czech figures present a slight increase in both the backward and forward cases; however, the former has a stronger dynamic and hence the Czech automotive industry relatively shifted to a downstream position. The ratios of the different length parts reflect stability in time, though the structures are different. The GVC stages are the dominant parts in all cases but have a higher ratio in the forward length. In accordance with the former analysis the domestic stages are longer as well as the traditional final product trade part is stronger in the Czech case. The Czech automotive industry length is outstanding in international comparison too; in addition, the backward stages and hence the downstream characteristics are relatively strong.

Figure 4: The change and the structure of the GVC lengths



Note: PLf = forward length; PLb = backword length; D = domestic part; RT = range of the traditional trade of final products; GVC = length of the simple and complex global value chain parts.

Source: own elaboration by UIBE

The international input-output tables provide the possibility to trace all the direct country-industry inputs and expenditures. Table 1 reflects the contributing links in the sequence of the latest year values. The dark grey area indicates the first third most important links, the light grey bar contains the first 50% of the cumulated values. The tables reflect at first sight that the Czech value chain is more concentrated than the Hungarian links. In addition, the majority of the backword connections are local in Czechia while the Hungarian links mostly range to Germany. In accordance with the importance of imports (see Figure 1) the table describes the detailed structure of the imports both in terms of countries and industries.

As far as the contributing industries are concerned, the technological relations are similar in both countries and quite concentrated to 4-7 main industries including the input of the motor vehicle industry itself. However, while the local contributions contain high value-added industries and services – similar to the German supply – in Czechia, the Hungarian local industries contribute much less to the process; in this case the German, Czech and Austrian value-added take the majority. Regarding the motor vehicle industry itself the local contribution in Czechia is around 20%, while it is 1.1% of the intermediate consumption (excluding value added!) in Hungary.

The changes of contributing industries and countries in time also deserve attention. In the case of Czechia, Poland, Slovakia and Korea denote a remarkable relative increasing role, all as a supplier in the motor vehicle industry. Moreover, it is worth noting that the Czech local links have moved from a lower value-added contribution (manufacture of basic metals, fabricated metal product, rubber and plastic) to higher value-added levels. In Hungary the most remarkable fact is the drastic shift from the local contribution to mainly German and Czech suppliers, and an increase in the participation of Poland, Slovakia, Korea and China. The Japanese role seems to shrink over time; however, the importance of Suzuki questioned these data. The fall back of Hungary appears mainly in the high value-added stages such as automotive industry production and the manufacture of machinery and equipment. It is also a remarkable change that the computer, electronic and optical products contribution moved from Germany to China over time.

Table 1: Main backword links by country-industry, direct (in the sequence of 2014 values)

Czechia

Code	Industry	Country	CZE2000	CZE2005	CZE2010	CZE2014	2014 cum%
C29	Manufacture of motor vehicles, trailers and semi-trailers	CZE	18,54	12,61	16,75	19,68	19,68
C29	Manufacture of motor vehicles, trailers and semi-trailers	DEU	9,21	10,49	8,76	8,67	28,36
C22	Manufacture of rubber and plastic products	CZE	7,67	8,39	6,73	5,23	33,59
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	CZE	4,91	5,61	5,48	4,15	37,74
C29	Manufacture of motor vehicles, trailers and semi-trailers	POL	0,44	1,00	2,66	2,94	40,68
C22	Manufacture of rubber and plastic products	DEU	3,23	3,15	2,98	2,92	43,60
G47	Retail trade, except of motor vehicles and motorcycles	CZE	3,44	3,81	3,51	2,81	46,42
G46	Wholesale trade, except of motor vehicles and motorcycles	CZE	2,21	1,87	2,64	2,78	49,19
C27	Manufacture of electrical equipment	DEU	3,09	2,49	3,02	2,76	51,96
C29	Manufacture of motor vehicles, trailers and semi-trailers	SVK	0,42	0,54	1,47	2,32	54,27
C29	Manufacture of motor vehicles, trailers and semi-trailers	KOR	0,01	0,01	0,85	1,92	56,19
H49	Land transport and transport via pipelines	CZE	1,06	1,46	1,75	1,51	57,71
C25	Manufacture of fabricated metal products, except machinery and equipment	CZE	3,06	2,84	1,84	1,45	59,16
C29	Manufacture of motor vehicles, trailers and semi-trailers	ROW	0,31	0,21	0,48	1,45	60,61
C24	Manufacture of basic metals	DEU	0,95	1,18	1,23	1,11	61,72
C24	Manufacture of basic metals	CZE	4,07	3,22	1,60	1,05	62,76
C29	Manufacture of motor vehicles, trailers and semi-trailers	HUN	0,41	2,42	1,11	0,95	63,71
C29	Manufacture of motor vehicles, trailers and semi-trailers	FRA	0,97	1,46	1,01	0,89	64,61
C29	Manufacture of motor vehicles, trailers and semi-trailers	ITA	0,47	0,74	0,64	0,76	65,36
C28	Manufacture of machinery and equipment n.e.c.	DEU	0,69	0,67	0,66	0,71	66,07

Hungary

Code	Industry	Country	HUN2000	HUN2005	HUN2010	HUN2014	2014 cum%
C29	Manufacture of motor vehicles, trailers and semi-trailers	DEU	8,82	9,83	8,42	13,89	13,89
C28	Manufacture of machinery and equipment n.e.c.	DEU	8,15	11,73	12,03	10,80	24,68
C27	Manufacture of electrical equipment	DEU	2,14	2,38	2,01	2,70	27,38
C25	Manufacture of fabricated metal products, except machinery and equipment	HUN	3,44	2,49	3,28	2,35	29,73
C29	Manufacture of motor vehicles, trailers and semi-trailers	CZE	0,22	1,63	1,38	2,27	32,00
C29	Manufacture of motor vehicles, trailers and semi-trailers	AUT	1,10	1,16	1,27	1,87	33,88
C29	Manufacture of motor vehicles, trailers and semi-trailers	POL	0,46	1,33	2,05	1,63	35,51
C25	Manufacture of fabricated metal products, except machinery and equipment	DEU	1,19	1,33	1,17	1,51	37,02
C28	Manufacture of machinery and equipment n.e.c.	ITA	0,76	1,80	0,62	1,49	38,51
C26	Manufacture of computer, electronic and optical products	CHN	0,56	1,11	1,26	1,47	39,98
C28	Manufacture of machinery and equipment n.e.c.	HUN	6,10	2,02	4,37	1,36	41,34
G46	Wholesale trade, except of motor vehicles and motorcycles	DEU	0,77	1,13	0,92	1,27	42,61
N	Administrative and support service activities	HUN	0,70	1,61	1,17	1,17	43,78
H49	Land transport and transport via pipelines	HUN	0,56	0,85	0,88	1,15	44,93
C29	Manufacture of motor vehicles, trailers and semi-trailers	HUN	12,49	3,05	5,74	1,11	46,04
G46	Wholesale trade, except of motor vehicles and motorcycles	HUN	1,27	1,45	1,68	1,10	47,13
C26	Manufacture of computer, electronic and optical products	DEU	2,15	0,62	1,27	1,07	48,20
C29	Manufacture of motor vehicles, trailers and semi-trailers	JPN	1,12	1,34	1,17	0,99	49,20
C30	Manufacture of other transport equipment	USA	0,39	1,05	0,47	0,99	50,19
C29	Manufacture of motor vehicles, trailers and semi-trailers	ITA	0,58	1,14	0,95	0,97	51,16

Source: own calculation and elaboration by UIBE

3.2 Interviews

Our company interviews could supplement well the results of the data analysis. The interviews reinforced the large differences between the use of local suppliers in the two automotive industries. Indeed, in Hungary, the interviewed OEMs and experts indicated very low local value added by local firms in the case of the two German carmakers. However, the Japanese Suzuki deploys a relatively extensive network of local suppliers, consisting of 239 Tier-1 suppliers, of which 27 firms are locally owned. The reason for the difference between the German and Japanese carmakers is that it had to reach 50 % local content in order to be able to export free of tariffs its products to the rest of the European Union. For German OEMs, this EU-content by definition is there without local, Hungarian suppliers. They basically do not have any Hungarian-owned suppliers (though have quite many foreign-owned suppliers operating in Hungary) and the overwhelming majority of parts and components comes from imports. In Czechia, there is wide range of local automotive suppliers covering both multinationals (usually occupying tiers 0.5-2) and domestically owned firms (in most cases tier 2 or 3 suppliers). Nonetheless, foreign owned suppliers typically source most of their inputs from abroad, with a maximum range of 500 to 800 km. This is related to corporate strategies as well as the fact that local firms are often not capable to supply inputs in required amount and/or quality. Despite of that, there is higher embeddedness of local firms (both domestic and foreign owned) in Czechia compared to Hungary.

Our interviews also reinforced the dominance of forward links in Hungary. Indeed, our expert interviews showed that Hungary is relatively more specialised in parts and components production, in spite of the fact that three carmakers are present in the country with assembling. This is underlined by the fact that the time period covered by the input-output analysis ends in 2014, when the production of Mercedes was not full-fledged yet. On the other hand, important producers of parts and components from Germany (e.g. Knorr-Bremse, Robert Bosch, Continental, Harman Becker), from other European and non-European countries (e.g. the Austrian AVL, the Canadian Linamar, the French Michelin or Valeo, the Indian SMR, the Japanese Denso, the Korean Hankook, the US Jabil or Lear) are determining players in the Hungarian automotive industry. They not only supply the local subsidiaries of carmaking multinationals, but also export intensively to other countries. In Czechia, the operations of three OEMs (Škoda, Toyota and Hyundai) and the fact that Czechia produces twice as many cars as Hungary also means lower complex forward linkages. Even so, interviewed automotive suppliers export the majority of their products, on average almost 90% of their production.

The data showed the differences in the length of production in the two countries. Our interviews reinforced, that Hungary is highly specialised in certain, mainly production-related activities and very limited is the service value added content. For example, R&D activities of both independent centres (foreign-owned) and production-related, though slowly growing, is still quite limited. In Czechia, there are several large automotive R&D units (e.g. Valeo, Bosch), and there are also R&D in Czech companies, though this is limited to just a few of them. All interviewed companies confirm increased R&D expenditure and moving up to more sophisticated countries. According to respondents, Czechia is now termed the best-cost country rather than a low-cost country. Therefore, some of the low-value added activities have already been relocated.

The dominant input sourcing from Germany by the Hungarian automotive industry is also indicated by the interviews. This is on one hand due to the establishment and operation of the Mercedes factors, which concentrates on assembling activities. Furthermore, as we mentioned above, even the overwhelming majority of local links are to foreign (in many cases German) owned subsidiaries. The same applies to Czechia, where most inputs come from Germany or localized branches of German multinationals. This is not the case for Hyundai, though, where the inputs either stem from co-located Hyundai suppliers (e.g. Mobis, Transys), other Huyndai suppliers located in neighbouring countries (Slovakia, Poland) or from Asia, particularly Korea.

The lower local value added in Hungary compared to Czechia can be seen already from the above excerpts from the interviews. There are only a few locally owned companies supplying the local subsidiaries, mainly that of Suzuki, with various parts and components. We interviewed two of these companies. One of them is medium-sized and supplies only Suzuki, the other one is a large company, and besides Suzuki, large truckmakers (among others) are its most important partners. Furthermore, though there is a slow increase in local value added, two carmakers concentrate on assembling and Audi produces engines as well. Despite relatively higher value added in Czech automotive sector, domestically owned firms point out to significant rigidity and limited possibility for upgrading in the automotive sector. Further, most 3-tier suppliers are in a captive position.

In Hungary, we have found an explanation for the declining importance of Japanese imported inputs from our interviews. While at the beginning of its production, Suzuki relied to a great extent on imported inputs from Japan, later on, when the number of cars produced, reached a higher level, and thus it was worth for these Japanese suppliers to follow their partner to Hungary and establish a subsidiary, as economies of scale factors were now present. This threshold level was reached before the 2008-9 financial crisis, and we can see the establishment of Japanese component-producing subsidiaries in Hungary since around 2008. Thus, there is still a considerable extent of Japanese inputs, produced by Japanese-owned subsidiaries, though not in Japan but in Hungary. In Czechia, the increasing role of backward links from Korea are related to the establishment of Hyundai Motor Manufacturing Czech in 2006.

4. Conclusion

Both Czechia and Hungary are highly integrated into automotive global value chains. However, their positions in the GVCs differ. The analysis of the international input-output tables has revealed that in the case of Czechia the international value chains of the automotive industry production are more concentrated both in terms of the supplying industries and regarding the geographic location of suppliers (Poland, Slovakia, Germany): the importance of the simple value chains is stronger than in Hungary, even if the length of the global value chains are longer in absolute terms. In addition, the concentration involves the powerful local supply chains as well. In terms of dynamics the complex links are extending as well as there is a shift towards a downstream position with higher value added stages of production.

The Hungarian automotive value chains are more internationally networked with high participation and import contribution, the latter is mainly concentrated to Germany. The network is much diverse than the Czech pattern; however, more concentrated by value. The main experience is the shift from the local to the German and partly Czech backward production links while the value added content has diminished. The position faces an upstream shift with a highly concentrated backward structure. The emerging domestic links and the fall of the Japanese relationship have called for a critical discussion of the data and demand the ownership analysis of the domestic production. The distinct position of Czech and Hungarian firms in automotive GVCs has been confirmed by interviews among OEM and automotive suppliers. Despite high backward linkages in both countries, OEM and automotive suppliers are more embedded in Czechia than in Hungary. This is in line with the findings of other studies (e.g. Pavlínek, 2021).

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Analysis of the impact of stricter emission standards on the development of the share price of European car makers between years 2011 and 2020

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Abstract

This paper is devoted to the tightening of emission standards in the EU and their impact on the value of the largest European car makers. The paper focuses mainly on the reasons and links between the tightening of emission standards and the value of major European car makers on the stock market, considering both the technical view of the matter and, of course, the financial view. This paper puts its findings into perspective and considers current trends in the automotive industry and its prospects for the future. As a result, this paper compares the stocks performance of the biggest European car makers to the average performance of biggest European stock indexes such as CAC40 and DAX30 that all the chosen car makers are (or were) part of. The findings of the paper help to specify when and why the stricter emission standards in EU started to be considered as a threat to the automotive industry even by the investors on stock market.

Keywords: car manufacturers, emission standards, European Union, stock market

JEL Classification: G1 Asset Markets and Pricing, L51 Economics of Regulation, O32 Management of Technological Innovation and R&D

1. Introduction

In the last couple of years, we had a chance to witness various restrictions and changes all over the world which only purpose was (and still is) to ensure slower global warming and cleaner world for the generations to come. However, these goals are not the priority number one for all governments. Especially for the developing countries the concern about pollution is not so important. On the other hand, the developed countries try to find a common solution and many countries are collaborating to reach these goals together. One of the means how these countries would like to reach carbon neutral future is to reduce carbon footprint of passenger cars with internal combustion engines (also known as ICE vehicles).

Although the global effort of these countries is consistent (to reduce emissions from passenger cars), most countries use different approaches to reach this goal (Krabec, Čižinská, 2020, Neset, Čižinská, 2021). In terms of reducing emissions produced by cars, we can say that it is the European Union who is setting an example for other countries because in European Union the emission standards are relatively stricter than in other parts of the world (ICCT [online], 2021).

In the European Union, car manufacturers must comply with very strict emission limits, otherwise they risk being fined for exceeding them. These emission limits have a purpose of reducing the production of harmful substances (mostly nitrogen oxides and carbon oxides and other) by ICE vehicles. In addition, these emission standards get stricter over the time and car manufacturers who sell cars in European Union must adjust to it. The problem is that current emission standards in Europe are already strict as they are but there are even stricter emission standards to come (Euro 7 in 2025) (ACEA [online], 2021). Already current emission limits represent quite a challenge for automakers because due to increasingly stringent emission standards, carmakers are reaching the very limit of the capabilities of internal combustion engines, whose level of efficiency is at most around 35% with current technologies (Prouza, 2015, p. 16).

This paper establishes the connection between the stricter emission standards for ICE vehicles in European Union and the value (Krabec, 2007, Krabec, 2014) of biggest car manufacturers in Europe on the stock market by market capitalisation using the financial data from annual reports from the biggest European car manufacturers and from sales statistics and at the same time considering technological advancements made in the last couple of years (see also Krabec, Čižinská, 2015).

2. Problem Formulation and Methodology

As the introduction suggested, stricter emission standards represent serious threat to the automotive industry in Europe and especially to those car manufacturers that will be not able to adapt from the technological point of view. To meet stricter emission standards the car manufacturers must invest into alternative means of propulsion (other than ICE only powered cars with which the car manufacturers wonít be able to meet neither current emission limits nor the future emission limits). Unfortunately for the car manufacturers, the main problem with alternative means of propulsion is that these propulsions (such as hybrids, plug-in hybrids or electric) are relatively more expensive to produce than ICE only powered cars (PA Consulting, 2019).

To achieve lower emissions, carmakers have had to implement a lot of new technologies to their cars in recent years. These were usually catalytic convertors, particulate filters, selective catalytic reduction, mild-hybrid drives, etc. The adoption of these new technologies meant that the variable costs of each car produced to go up. But this is not the only problem that the car manufacturers have to face with current and coming emission standards. There is one major problem, namely that ICE vehicles are no longer able to meet current (let alone future) emission limits even with all the technologies mentioned above that were implemented in new cars over last couple of years. And as most automakers try to avoid paying fines for exceeding emission limits, they have had to develop alternative propulsions that have lower o better zero local emissions.

However, investing in these alternative propulsions required a lot of resources which had a negative impact on financial results of some car manufacturers that resulted into poor performance of their stocks on stock market (see in the next chapters).

This work will therefore take into account the financial results of car manufacturers in the context of emission standards in the EU and based on this knowledge we will compare the performance of car manufacturers on the stock market with the performance of the most important European stock indices.

2.1 Model and Data

To be able to find the results to our problem, we have to take the data from stock markets, mainly the year over year performance of the major European car manufacturers and then compare the performance of these particular stocks to the performance of important European stock indices. In the model we take into consideration only major car European car companies that realize significant part of its sales in Europe which ensures that their core businesses (ie selling cars) are affected by the stricter emission standards created by the European Union. The companies that we studied are: Volkswagen group (Volkswagen, Audi, Skoda, Seat, Bugatti, Lamborghini, Cupra and Bentley), Renault Group (Renault, Dacia, Lada, Alpine), PSA Group / Stellantis (Peugeot, Citroen, DS and Opel, Abarth, Alfa Romeo, Dodge, Fiat, Jeep, Lancia, Maserati and Ram Trucks), Daimler (Maybach, Mercedes-Benz and Smart) and BMW (BMW, Mini and Rolls-Royce).

As the stocks of these chosen car manufacturers are publicly traded on major stock exchanges in Europe and as they are part of major stock indices in its countries, we compared their year over year performance with the year over year performance of the indices that they are part of. These indices are German DAX 30 and French CAC 40, where BMW, Daimler and Volkswagen are part of German DAX 30 and Renault with Peugeot (group PSA) are part of French index CAC 40.

It is also important to mention that both indices are composed of the biggest companies in that particular country, so the comparison with the chosen big car manufacturers that are part of these indices is relevant.

2.1.1 Model Calibration

The overview of the year over year performance of both indices can be found in Table 1. This table will be used as a base data set to compare the year over year performance to the average performance of the car manufacturers stocks.

Then the Table 2 presents the year over year performances of individual car manufacturers stocks. It is important to mention that the development of the value of individual shares was influenced by the relative success of the car manufacturer in individual years, meanwhile the performance of both indices was rather affected by relative growth of the economy either in Germany or in France.

Table 1: Comparison of the performance of national indices CAC 40 and DAX 30 between 2006 and 2021

Comparison of the performance of national indices CAC 40 and DAX 30 between 2006 and 2021				
Year	**CAC 40 closing price as of 31 December**	**CAC 40 YOY change**	**DAX 30 closing price as of 31 December**	**DAX 30 YOY change**
2005	4715,23	x	4256,08	x
2006	5541,76	17,53%	5408,26	27,07%
2007	5614,08	1,31%	6596,92	21,98%
2008	3217,97	-42,68%	8067,32	22,29%
2009	3936,33	22,32%	4810,2	-40,37%
2010	3804,78	-3,34%	5957,43	23,85%
2011	3159,81	-16,95%	6914,19	16,06%
2012	3641,07	15,23%	5898,35	-14,69%
2013	4295,95	17,99%	7612,39	29,06%
2014	4272,75	-0,54%	9552,16	25,48%
2015	4637,06	8,53%	10743,01	12,47%
2016	4862,31	4,86%	11481,06	6,87%
2017	5312,56	9,26%	12917,64	12,51%
2018	4730,69	-10,95%	10558,96	-18,26%
2019	5978,06	26,37%	13249,01	25,48%
2020	5551,41	-7,14%	13718,78	3,55%
2021	7153,03	28,85%	15884,86	15,79%

Source: Own data collection and processing based on information available from: https://www.investing.com

To be able to compare the performance of the indices to the performance of car manufacturers on stock market, we used simple averages. It means that the performance of German companies (BMW, Daimler and Volkswagen) was compared to the performance of German index DAX 30 and that the performance of French companies was compared to the performance of French index CAC 40. This means that for example the year over year performance of Daimler was compared to the year over year performance of index DAX 30 every single year for the chosen time period. This calculation was done with every car manufacturer and every index of which the car manufacturer is a part of. Then those 5 averages (of those 5 carmakers) were summed and divided by five (total number of car manufacturers that this was counted for). This enabled to create Table 3 that shows the direct comparison of performance of car manufacturers to the performance to the indices on the stock market (in broader context see also Šaroch et all, 2021).

Table 2: Performance of individual stocks in the period between 2006 and 2021

Performance of individual stocks in the period between 2006 and 2021 (closing prices as of the last trading day of the given year in Euros)										
Year	**VW**	**YOY change**	**BMW**	**YOY change**	**Daimler**	**YOY change**	**Renault**	**YOY change**	**Peugeot**	**YOY change**
2005	32,157	x	37,000	x	43,080	x	68,600	x	31,020	x
2006	56,133	74,6%	43,600	17,8%	46,930	8,9%	91,270	33,0%	31,97	3,1%
2007	98,718	75,9%	42,730	-2,0%	66,210	41,1%	97,460	6,8%	33,03	3,3%
2008	38,628	-60,9%	21,970	-48,6%	26,400	-60,1%	17,520	-82,0%	7,74	-76,6%
2009	64,722	67,6%	32,000	45,7%	37,170	40,8%	35,590	103,1%	15,07	94,7%
2010	121,810	88,2%	58,710	83,5%	50,920	37,0%	43,270	21,6%	18,10	20,1%
2011	115,146	-5,5%	51,545	-12,2%	33,768	-33,7%	26,605	-38,5%	7,71	-57,4%
2012	172,265	49,6%	73,088	41,8%	41,424	22,7%	40,500	52,2%	3,99	-48,2%
2013	204,368	18,6%	85,501	17,0%	63,069	52,3%	58,400	44,2%	6,89	72,7%
2014	184,945	-9,5%	90,069	5,3%	69,517	10,2%	60,690	3,9%	10,22	48,3%
2015	134,356	-27,4%	98,120	8,9%	77,895	12,1%	94,035	54,9%	16,20	58,5%
2016	133,435	-0,7%	88,814	-9,5%	70,708	-9,2%	83,980	-10,7%	15,49	-4,4%
2017	166,785	25,0%	87,061	-2,0%	70,726	0,0%	83,780	-0,2%	16,95	9,4%
2018	139,360	-16,4%	70,570	-18,9%	45,785	-35,3%	53,910	-35,7%	18,64	10,0%
2019	176,420	26,6%	73,320	3,9%	49,305	7,7%	42,870	-20,5%	21,30	14,3%
2020	151,480	-14,1%	72,750	-0,8%	58,350	18,3%	36,175	-15,6%	22,37	5,0%
2021	177,100	16,9%	88,390	21,5%	67,720	16,10%	29,785	-17,7%	16,67	-25,5%

Source: Own data collection and processing based on information available from: https://www.boerse-frankfurt.de

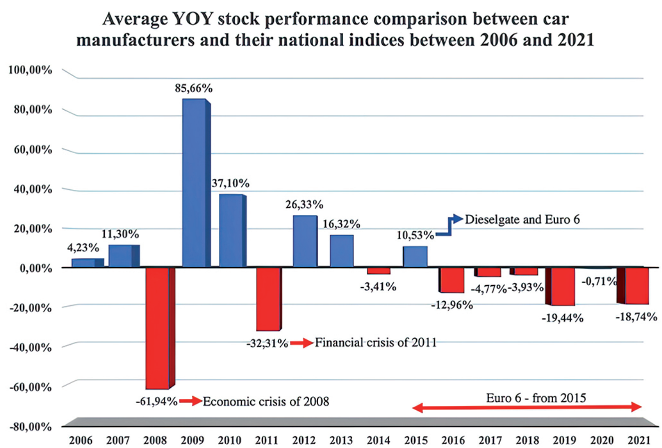
The data collected in the Table 3 were later used in the Chart 1 where we can see the results of a direct comparison of the year over year performance of particular stocks and the indices that these stocks are part of.

3. Problem Solution

Looking at the Table 3 (Direct comparison of YOY performance of car manufacturers to the YOY performance of national indices) and Chart 1 (Average YOY stock performance comparison between car manufacturers and their national indices) we can claim that the final results in Chart 1 were in certain years affected by some big drops or big gains realized by particular stocks within 1 year.

On the other hand, the Chart 1 nicely illustrates one basic long-term development of the car manufacturers stocks in comparison with major national indices that these car manufacturers are part of. The Euro 6 emission standard was put into place for all new vehicles in September 2015 (ACEA [online], 2021). Until its introduction, car manufacturers shares performed better than the national indices that they are part of by 9,36 % per year in the period between 2006 and 2015. On the contrary, since 2016 (ie the year following the introduction of the Euro 6 emission standard), the shares of the monitored car manufacturers performed significantly worse than the national indices (between 2016 and 2021 car manufacturers performed worse than the national indices by 10,09 % than national indices). Given the fact that Euro 6 was introduced in in September of 2015, we can say that the Chart 1 illustrates the negative affect the regulation (in this case emission standards Euro) has on automotive industry.

Chart 1: Average YOY stock performance comparison between car manufacturers and their national indices



Source: Own data collection and processing based on information in Table 1, 2 and 3.

As we all know, Euro 6 is the first emission standard that has been challenging from the technical perspective (as mentioned earlier in the text) to most car manufacturers. At the same time current emission standards severally affect the need of investing into research and development of which the costs are rising, it affects margin, profit and prices of final outputs (cars) etc. If we take possible fines for exceeding the emission limits into consideration, we can say that car manufacturers have no other option than to invest research and development and come up with new technologies that will help them to fulfil the strict requirements.

Charts (2, 3 and 4) showing the growth of research and development costs of the monitored car manufacturers and the deterioration of financial results (profit) despite the sale of a larger number of new vehicles until 2020, can be found in the appendix of the paper itself as a proof of the conclusions mentioned above.

It is necessary to admit that there are several reasons that can be used to explain underperforming of car manufacturers' shares since 2016 despite the fact that the European car market was flourishing until the beginning of 2020. It should be borne in mind that stricter emission standards do not cause the decrease in the performance of car manufacturers' shares directly. It is predominantly the "trigger" of the domino effect, that causes rise of research and development costs, production costs, etc.

Therefore, the deteriorating financial results together with not very positive outlook for the future mainly due to strict emission standards, made the carmaker's shares less attractive to investors than the shares of other companies. These investors' assumptions did not refute even the record sales in the period prior the COVID-19 pandemic (Grunt, 2021). As an alternative explanation of sudden underperforming of car manufacturers' shares since 2016 can also be considered the scandal of Volkswagen in 2015 resulting into the loss of investor confidence not only in the honesty of carmakers but also in their ability to adapt to more stringent emissions standards. On the other hand, if it was the case, Volkswagen's shares probably wouldn't reach the same record price hights in 2021 as they had back in 2015, before the scandal was released.

4. Conclusion

As far as we know, this is the first paper that analyses the impact of European emission standards on the value of European car manufacturers in the stock market and the paper leads to a clear result. Stricter emission standards have negative effect on the value of car manufacturers in the stock market. Comparing the year over year performance of car manufacturers shares to the stock indices, it is apparent that since the emission standard Euro 6 was introduced, the stocks of car manufacturers perform worse than the indices that they are part of even though they did better until the introduction of the Euro 6 emission standard.

This paper can therefore be used as a proof that the tightening of emission standards in automotive must corelate with the technological advancement if the regulation wants to be successful. Once the tightening of emission standards is too quick, many car manufacturers might get into problem and as automotive industry is very important in Europe, this might bring serious problems. Looking at the development of the share price of selected car manufacturers and their comparison with stock indices, it can be argued that even investors in the stock markets are aware of the difficulties that the Euro 6 emission standard brings with it.

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Appendix

Table 3: Direct comparison of YOY performance of car manufacturers to the YOY performance of national indices

Direct comparison of YOY performance of car manufacturers to the YOY performance of national indices between 2006 and 2021							
YOY performance of DAX 30 vs. BMW AG between 2006 and 2021				YOY performance of DAX 30 vs. Daimler AG between 2006 and 2021			
Year	DAX30	BMW	Better x worse by	Year	DAX30	Daimler	Better x worse by
2006	27,07%	17,84%	-9,23%	2006	27,07%	8,94%	-18,13%
2007	21,98%	-2,00%	-23,97%	2007	21,98%	41,08%	19,10%
2008	22,29%	-48,58%	-70,87%	2008	22,29%	-60,13%	-82,42%
2009	-40,37%	45,65%	86,03%	2009	-40,37%	40,80%	81,17%
2010	23,85%	83,47%	59,62%	2010	23,85%	36,99%	13,14%
2011	16,06%	-12,20%	-28,26%	2011	16,06%	-33,68%	-49,74%
2012	-14,69%	41,79%	56,49%	2012	-14,69%	22,67%	37,36%
2013	29,06%	16,98%	-12,08%	2013	29,06%	52,25%	23,19%
2014	25,48%	5,34%	-20,14%	2014	25,48%	10,22%	-15,26%
2015	12,47%	8,94%	-3,53%	2015	12,47%	12,05%	-0,42%
2016	6,87%	-9,48%	-16,35%	2016	6,87%	-9,23%	-16,10%
2017	12,51%	-1,97%	-14,49%	2017	12,51%	0,03%	-12,49%
2018	-18,26%	-18,94%	-0,68%	2018	-18,26%	-35,26%	-17,00%
2019	25,48%	3,90%	-21,58%	2019	25,48%	7,69%	-17,79%
2020	3,55%	-0,78%	-4,32%	2020	3,55%	18,34%	14,80%
2021	15,79%	21,50%	5,71%	2021	15,79%	16,10%	0,31%
YOY performance of CAC 40 vs. Peugeot SA (Stellantis) between 2006 and 2021				YOY performance of CAC 40 vs. Renault SA between 2006 and 2021			
Year	CAC40	Peugeot	Better x worse by	Year	CAC40	Renault	Better x worse by
2006	17,53%	3,06%	-14,47%	2006	17,53%	33,05%	15,52%
2007	1,31%	3,32%	2,01%	2007	1,31%	6,78%	5,48%
2008	-42,68%	-76,57%	-33,89%	2008	-42,68%	-82,02%	-39,34%
2009	22,32%	94,70%	72,38%	2009	22,32%	103,14%	80,82%
2010	-3,34%	20,11%	23,45%	2010	-3,34%	21,58%	24,92%
2011	-16,95%	-57,40%	-40,45%	2011	-16,95%	-38,51%	-21,56%
2012	15,23%	-48,25%	-63,48%	2012	15,23%	52,23%	37,00%
2013	17,99%	72,68%	54,70%	2013	17,99%	44,20%	26,21%
2014	-0,54%	48,33%	48,87%	2014	-0,54%	3,92%	4,46%
2015	8,53%	58,51%	49,99%	2015	8,53%	54,94%	46,42%

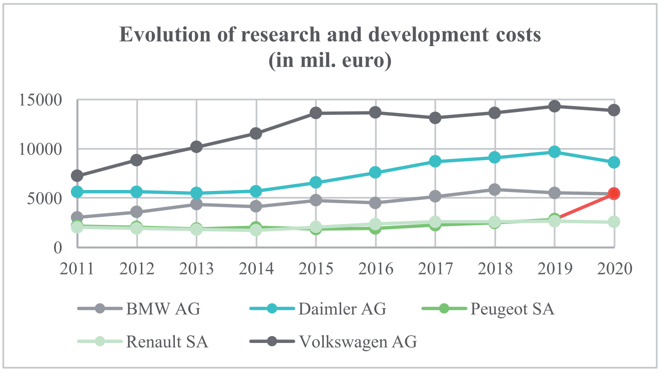
2016	4,86%	-4,38%	**-9,24%**	**2016**	4,86%	-10,69%	**-15,55%**
2017	9,26%	9,43%	**0,17%**	**2017**	9,26%	-0,24%	**-9,50%**
2018	-10,95%	9,97%	**20,92%**	**2018**	-10,95%	-35,65%	**-24,70%**
2019	26,37%	14,27%	**-12,10%**	**2019**	26,37%	-20,48%	**-46,85%**
2020	-7,14%	5,02%	**12,16%**	**2020**	-7,14%	-15,62%	**-8,48%**
2021	28,85%	-25,47%	**-54,32%**	**2021**	28,85%	-17,66%	**-46,51%**

YOY performance of DAX 30 vs. Volkswagen AG between 2006 and 2021

Year	DAX30	Volkswagen	Better x worse by
2006	27,07%	74,56%	**47,49%**
2007	21,98%	75,86%	**53,89%**
2008	22,29%	-60,87%	**-83,16%**
2009	-40,37%	67,55%	**107,93%**
2010	23,85%	88,20%	**64,35%**
2011	16,06%	-5,47%	**-21,53%**
2012	-14,69%	49,61%	**64,30%**
2013	29,06%	18,64%	**-10,42%**
2014	25,48%	-9,50%	**-34,99%**
2015	12,47%	-27,35%	**-39,82%**
2016	6,87%	-0,69%	**-7,56%**
2017	12,51%	24,99%	**12,48%**
2018	-18,26%	-16,44%	**1,82%**
2019	25,48%	26,59%	**1,12%**
2020	3,55%	-14,14%	**-17,68%**
2021	15,79%	16,91%	**1,12%**

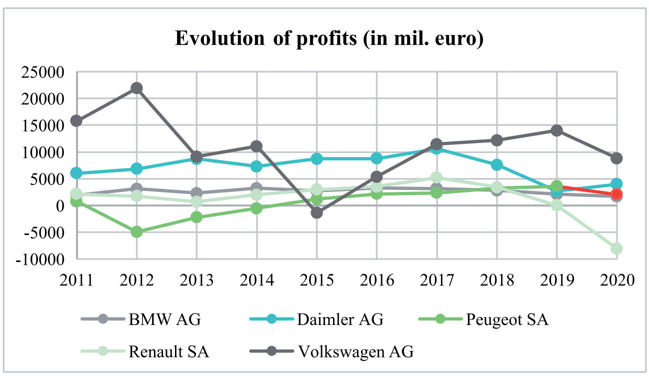
Source: Self data collection and processing based on information available from: https://www.boerse-frankfurt.de

Chart 2: Evolution of research and development costs (in mil. euro)



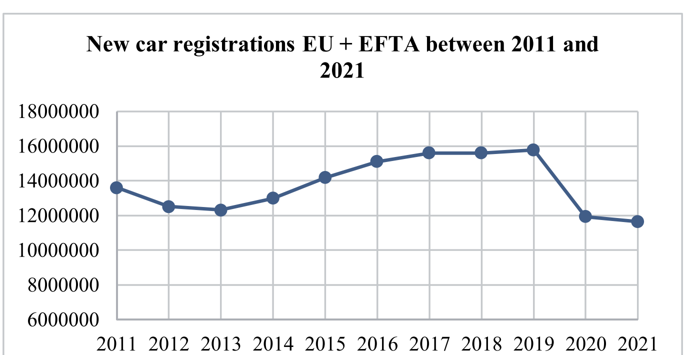
Source: Own processing based on data available from the annual reports of the companies

Chart 3: Evolution of profits (in mil. euro)



Source: Own processing based on data available from the annual reports of the companies

Chart 4: New car registrations EU + EFTA between 2011 and 2021



Source: Own processing based on data available from: https://www.acea.auto

Determination of Forging Press Clutch Loss

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Abstract

This paper describes different approaches to determine energy losses of clutch engagement on mechanical forging press. Mechanical forging press is a machine used to produce forgings which are widely used in drivelines and chassis groups of all cars. In the case of non-continuous cycle operation, the mechanism of the press is repeatedly started which is connected with considerable energy losses in case of conventional press drive. The clutch losses are caused by the physical nature of the impact of the bodies and the efficiency of the clutch engagement. The machine manufacturers determine the clutch losses by empirical calculations based on a long-term experience with press operations. However empirical calculations are only approximate so it is appropriate to use a modern simulation software. With its help, the mechanical design of the clutch can be optimized to increase its efficiency. With regard to the stress of the coupling components and their service life, it is necessary to look for their optimal design.

Keywords: forging press, energy consumption, friction clutch, energy

JEL Classification: C61, L61, L62

1. Introduction

Forging crank press is used to produce precise forgings widely used in automotive industry. Due to mass production every energy saving is important. The more important energy loss in drive side of press is clutch. Therefore it is our aim to study clutch with aim to reduce its loss (Varela, 2019).

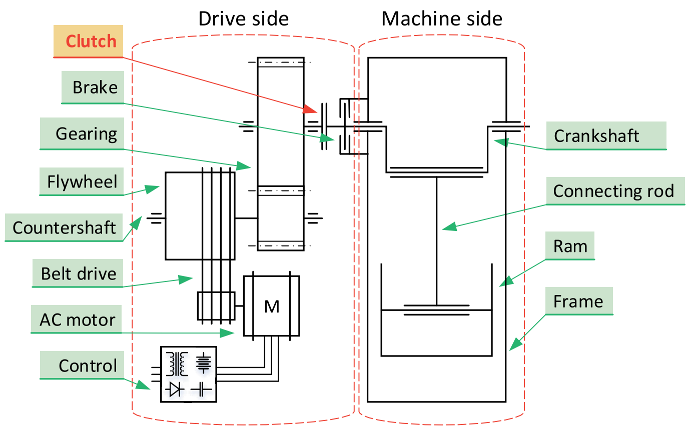
In the forging press drive the clutch is used to engage drive and machine side of machine. Clutch engaging is frequent due to intermittent operation. Intermittent operation is used to provide sufficient time to operate with forgings. While the forgings are operated used energy user energy is charged back to flywheel.

Every engaging of clutch is connected with slip - energy loss. It is possible to optimize drive and clutch to reduce this loss. To be able to reduce this loss it is important to prepare reliable simulation model describing clutch behaviour (Amandyk, 2019, p. 114-123).

1.1 Forging press

Typical crank press uses flywheel drive. Flywheel serves to accumulate the energy absorbed by the impact during forming. A typical arrangement is shown in Figure 1 (Hlaváč, 2022, p. 1–13). The press (Figure 1) consists of a machine part which is kinetically identical for all crank presses and the energy balance of most presses does not differ much. Energy savings in this part depend mainly on losses caused by friction, or on losses caused by elastic deformations of functional elements (Chval, 2014, p. 890–896). Drive part – there are various design variants. The drive is used to transform and transport of energy between AC motor a machine side. With flywheel drive it is necessary to use clutch to disengage drive and machine side.

Figure 1: Scheme of friction clutch used in forging press drive

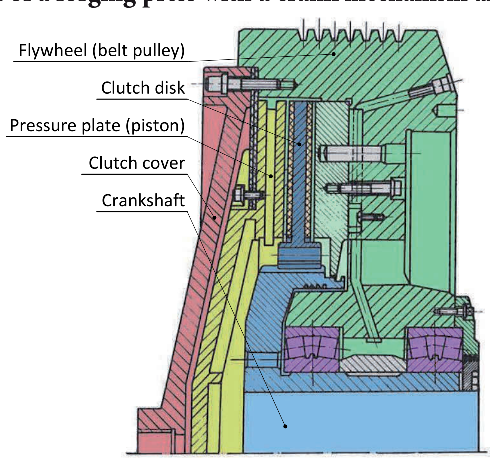


Source: Hlaváč, 2019, p. 1–13

1.2 Forging press clutch

Typical clutch of forging press is a dry frictional clutch. Usually the clutch is a push-type clutch, i.e. the clutch is initially in disengaged position. To engage the clutch a pneumatic cylinder and compressed air are used. An example of such a press clutch is in Figure 2.

Figure 2: Diagram of a forging press with a crank mechanism and a flywheel drive



Source: Kováč, 1978

Clutch design includes two load situations. The first load situation is a clutch engaging. While clutch engaging clutch transfers energy from running drive side to still standing machine side. Energy transfer is accompany by clutch slip where energy is lost - heat generation. Clutch overheating must be controlled. Second load situation is a maximum torque which occurs during forging (technology operation). High forces and torque in machine side occurs with forging technology.

2. Details of a 25MN forging press

In following chapters there are friction energy loss calculations. These calculations are all performed for the same press, with the same clutch. Technical description of such press is in Table 1.

Table 1: Technical parameters of the press

Nominal pressing force	F	25	[MN]
Transmitted torque	M	1.75	[MNm]
Useful work	A_u	225	[kJ]
Kinetic energy of a machine side	E_{kmech}	100	[kJ]
Angular velocity of the flywheel	ω	7.33	[rad/s]
Number of friction surfaces	n	4	[-]

2.1 Empirical approach

According to (Kamelander, 2019) the start-up work A_{start}, which is lost during clutch engagement, is approximately equal twice the amount of the braking work. This it because it composes of energy to start-up the mechanism, which is the same as the energy that needs to be withdrawn from the mechanism in order to stop it, and energy ΔE lost by clutch engagement. This energy ΔE is then dissipated in heat.

$$A_{start} = E_{k\,mech} + \Delta E \quad \rightarrow \quad \Delta E = A_{start} - A_{break} = \ 200 - 100 \cong 100\ kJ \qquad (1)$$

Results of this approach of calculations are valid only for ideal state. In reality the start-up work A_{start} is higher due to slippage that occurs while the actuating force is not yet high enough to engage the clutch.

2.2 Analytical approach

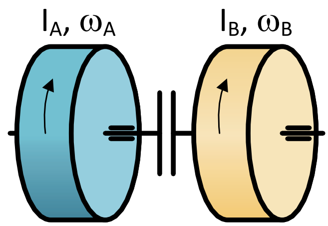
The clutch in the drive of press typically serves to connect and disconnect the flywheel (A) to the press mechanism (B) (Figure 3). Usually a dry friction air-operated disk clutch is used.

Assume that:

I_A	$[kg \cdot m^2]$	Moment of inertia – drive side
I_B	$[kg \cdot m^2]$	Moment of inertia – machine side
ω_A	$[s^{-1}]$	Angular velocity – drive side
ω_B	$[s^{-1}]$	Angular velocity – machine side

0	-	State before clutch engagement
1	-	State after clutch engagement
L	*[kg · m² · s⁻¹]*	Angular momentum
E	*[J]*	Energy

Figure 3: Schematic representation of connection of rotating masses by a coupling



Determination of the work lost by the clutch is based on the law of conservation of angular momentum and the law of conservation of energy.

The law of conservation of angular momentum states that the angular momentum of an isolated system of bodies is conserved. Then the following is valid:

$$L_{A0} + L_{B0} = L_1 \tag{2}$$

$$I_A \cdot \omega_{A0} + I_B \cdot \omega_{B0} = (I_A + I_B) \cdot \omega_1 \tag{3}$$

$$\omega_1 = \frac{I_A \cdot \omega_{A0} + I_B \cdot \omega_{B0}}{I_A + I_B} \tag{4}$$

The law of conservation of energy states that energy can neither be created nor destroyed; rather, it can only be transformed from one form to another. The energy of the clutch before engagement is equal to:

$$E_0 = E_{A0} + E_{B0} \tag{5}$$

$$E_{A0} = \frac{1}{2} \cdot I_A \cdot \omega_{A0}^2 \quad E_{B0} = \frac{1}{2} \cdot I_B \cdot \omega_{B0}^2 \tag{6}$$

$$E_0 = \frac{1}{2} \cdot (I_A \cdot \omega_{A0}^2 + I_B \cdot \omega_{B0}^2) \tag{7}$$

The decrease of kinetic energy after connecting both bodies is given by an irreversible increase of internal energy. In this case it is thermal energy. It is an inelastic impact. In an ideal inelastic impact the two bodies have the same velocity after collision (they do not move with respect to each other).

The energy of the system after clutch engagement and stabilizing rotational speed is equal to:

$$E_1 = \frac{1}{2} \cdot (I_A + I_B) \cdot \omega_1^2 \tag{8}$$

$$E_1 = \frac{1}{2} \cdot (I_A + I_B) \cdot \left(\frac{I_A \cdot \omega_{A0} + I_B \cdot \omega_{B0}}{I_A + I_B}\right)^2 = \frac{1}{2} \cdot \frac{(I_A \cdot \omega_{A0} + I_B \cdot \omega_{B0})^2}{I_A + I_B} \tag{9}$$

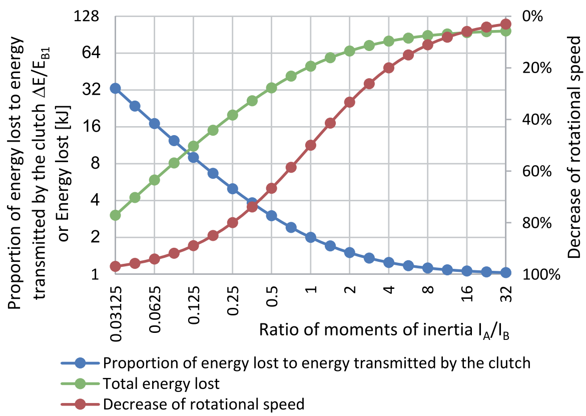
Loss of kinetic energy is equal to:

$$\Delta E = E_0 - E_1 = \frac{1}{2} \cdot \left(I_A \cdot \omega_{A0}^2 + I_B \cdot \omega_{B0}^2 - \frac{(I_A \cdot \omega_{A0} + I_B \cdot \omega_{B0})^2}{I_A + I_B} \right) \tag{10}$$

Energy loss solved by this method is ideal. In reality the energy loss will be higher due to clutch slippage caused by slow clutch engagement.
The difference of the system energy before and after clutch engagement is energy loss. The kinetic energy dissipates into thermal energy. To understand the relation between ratio of moments of inertia, transmitted energy and energy lost, see Figure 4.

$$\Delta E = E_0 - E_1 = 2\,363\,321 - 2\,267\,380 = 95\,940\,J \tag{11}$$

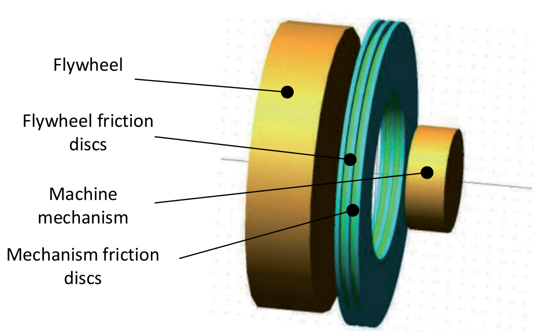
Figure 4: Dependence of energy lost by clutch on the moment of inertia of the flywheel



2.3 Simulation approach

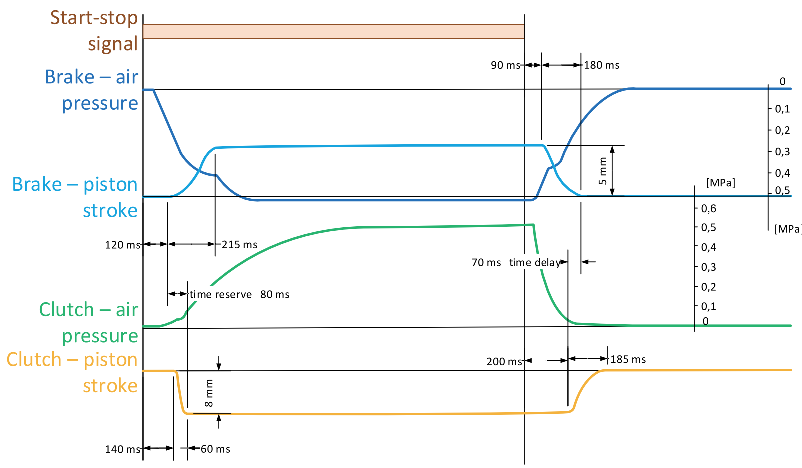
Multibody simulation is a method of numerical simulation consisting of rigid or elastic bodies connected by various kinematic constraints or force elements. Unilateral constraints, such as contacts, may be accompanied by Coulomb friction models etc. Ultimately it is a very powerful tool to investigate, optimize, and verify machine mechanisms. To investigate the friction clutch engagement we used MSC Adams/View software.

Figure 5: Multibody simulation model of a 5 disc friction clutch



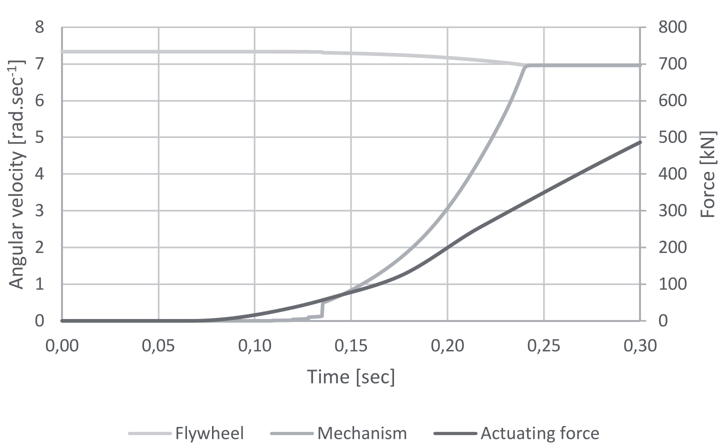
The multibody simulation is performed for the same clutch type as the previous calculations, i.e. the technical parameters are compliant. It is an air-actuated push-type friction clutch with 3 discs on the drive side and 2 discs on the machine side. The dynamic simulation model is shown in the Figure 5. With advantage we used available technical parameters and drawings of this clutch, as well as measurement record with several different parameters and variables measured on a real machine. The output of such measurement are time dependencies of air-pressure in the actuating cylinder, friction disc position, ram position, flywheel revolutions, etc. It is helpful to debug the simulation, see Figure 6.

Figure 6: Measurement record of a real press



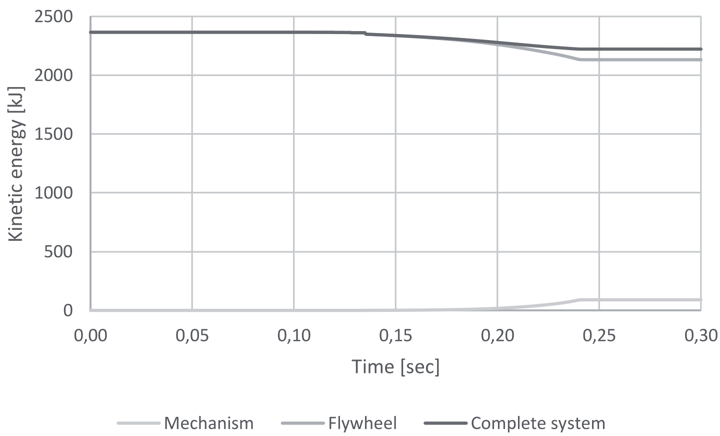
The results of a multibody simulation are plot of kinetic energy in the whole system and its parts, and plot of angular velocities of both drive side and machine side of the clutch. The kinetic energy plot shows the kinetic energy of the whole system as the sum of kinetic energy of both sides of the machine.

Figure 7: Plot of angular velocity and actuating force versus time



The plot of the angular velocities in the Figure 7 shows the time of full clutch engagement that occurs in . Also it show the plot of actuating force which is dependent on the air-pressure in the actuating cylinder. Until that time the friction discs are either not in contact or their surfaces are slipping relatively to each other.

Figure 8: Plot of kinetic energy versus time



The difference of the system energy before and after clutch engagement is energy loss and is shown Figure 8. The kinetic energy dissipates into thermal energy.

$$\Delta E = 2\ 365\ 463 - 2\ 222\ 336 = 143\ 127\ J \qquad (12)$$

3. Summary of the results

In the following Table 2 there are resulting values of energy losses obtained by all calculation approaches. The final values of empiric approach and analytic approach calculation are quite similar. The analytically calculated energy loss is the lowest physically possible. The result of a MBD simulation includes additional energy loss caused by slippage.

Table 2: Results of energy loss calculations

Energy lost in clutch engagement		
Empiric approach	100	kJ
Analytic approach	95.94	kJ
Simulation approach	143.12	kJ

4. Conclusion

From the results of empirical and analytical calculations, it is apparent that these describe ideal case which cannot occur in real machine. It is the lowest possible energy loss. In real machine, in real clutch, there is a slippage of all friction elements for a certain amount of time. This slippage is dependent on the construction design of the clutch, on the pressure force of the actuating cylinder, coefficient of friction, and other effects. Our work confirmed the possibility of using the multibody simulation and contributed accurate data of friction losses. With better knowledge of friction losses we can optimize mechanical design of friction clutches to lower their energy demands.

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Allocation of environmental costs in the automotive industry

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Abstract

The main aim of the submitted paper is to present ways, how to effectively allocate overhead costs with a focus on the environmental costs in the automotive industry. When the company operating in the automotive uses the outdated method of allocation of overhead costs, the final prices of its products do not correspond with the actually incurred costs and with the required margin. This situation crucially influences the market prices and demand in automotive as well. For this reason, the consumers should prefer environmentally harmful products and decrease the consumption of environmentally friendly products because the company incorrectly expressed the environmental costs on these products. Therefore, the company sells non-ecological products cheaper and ecologically friendly products more expensive in comparison with the situation when the company correctly allocated environmental costs during the production process.

Keywords: analysis, automotive industry, costing, environmental costs, indirect costs

JEL Classification: L2, M4, O3

1. Introduction

Nowadays, the automotive industry faces a lot of challenges and threats that influence the production process and the sale of their products all over the world. This situation has been caused by many factors such as the development of electromobility (Balali, Stegen, 2021), coronavirus pandemic, closed borders between countries, the lack of chips on the market (Pelle, Tabajdi, 2021), natural disasters, etc. All these circumstances incredibly changed the production process in the automotive industry. Suddenly, these companies had to solve many problems with insufficient shipments of material and human work. (Palazzo, Geyer, 2019)

At the same time, they reported a dramatic increase in costs incurred during the production process to ensure continuous production as much as possible. In addition, many car manufacturers and their suppliers were forced to stop their production for a limited time, because they were not able to finish their final products due to missing material and other important resources.

Related to the European market, the car producers must follow the European vehicle emission standards for exhaust emissions of new vehicles sold in the European Economic Area. It includes all the European Union member countries, Norway, Iceland, and

Liechtenstein. These mentioned strict rules force car manufacturers to decrease carbon dioxide emission and other harmful gases and exhausts. In addition, car producers are finding that it is more and more difficult to modify conventional internal combustion engines to be able to meet the set emission requirements. Therefore, we can see an effort to increase the share of electromobility in the EEA in response to these standards.

The situation in the automotive industry is currently very critical and for this reason, the car manufacturers and their suppliers must dramatically analyse all their costs to ensure the high financial soundness of the company. To be able to meet this goal, the accounting entity must correctly allocate all costs (direct and indirect) related to its production.

Therefore, the managers must implement specific rules to be able to manage costs in their company effectively. (Drury, 2013) They must know all processes realized in the company to understand and link the indirect costs with their consumption during the production of their products. (Mohr, 2017) This characteristic is possible to apply to environmental cost as well because among the most relevant criteria for products' selection are the environmental criteria. (Ballouki, Douimi, Ouzizi, 2018)

For this reason, reducing environmental costs has an immediate and substantial effect on the financial performance of the accounting entity. (Jo, Kim, Park, 2015) One of the possibilities of effective reporting and measurement of environmental costs is the implementation of environmental management accounting in the company. (Jamil, Mohamed, Muhammad, Ali, 2015)

The main aim of this paper is to present the modern way of allocation of environmental overhead costs on produced products to achieve their correct allocation on production and to express the cost variances between correctly and incorrectly allocated environmental costs on products.

2. Problem Formulation and Methodology

OECD defined the environmental costs as costs connected with the actual or potential deterioration of natural assets due to economic activities. (United Nations, 1997) They belong to one of the important groups of costs influencing the final price of produced products (Daniels, Steele, Sun, 2018), not only in the automotive industry. These costs are commonly incurred by accounting entities during the accounting period, and the company should report them in the environmental management accounting.

We consider the following types of environmental costs:

1. **Prevention costs** – costs related to the decrease of processing of wastes, emissions, and wastewater to ensure the lowest negative environmental impact of the company's activities.
2. **Appraisal costs** - costs incurred during the accounting period to ensure that the company complies with current environmental regulations such as monitoring environmental effects of all activities of the company that is responsible for.
3. **Internal failure costs** – costs that are incurred to eliminate the negative environmental impact of realized activities of the company.

4. **External failure costs** – costs incurred after discharging waste into the environment. The main aim of the entity is based on the reduction of waste and pollution of the environment.

The main idea of responsible reporting of environmental costs in the company is the possibility of reduction of the level of global warming caused by production process, hence, the detoxification of a production process and products, and finally to achieve a reduction of environmental impacts associated with resource extraction and processing. (Ekins, Zenghelis, 2021)

The above-mentioned environmental costs cannot be allocated directly to the produced inhomogeneous production, and the company must find a way of their appropriate allocation. For this reason, they are called overhead costs. (Constantin, Teodorescu, Nicolau, 2008) Some of these costs should be tax-deductible (such as costs ensuring environmental protection). On the other hand, tax-deductible when the company reports environmental costs like penalties paid for the illegal environmental pollution such as water or land poisoning, forbidden air pollution, etc.

Therefore, the fundamental problem lies in the fact that companies cannot comprehensively report completely all environmental costs as environmental costs belonging to mentioned groups of the environmental costs. Therefore, some of the environmental costs incurred during the accounting period are not assessed as environmental costs, and unfortunately, they are incorrectly allocated on all produced products.

Firstly, this situation leads to an increase of products' costs whose production was not responsible for wrongly allocated indirect environmental costs. Secondly, it leads to a decrease in the products' costs responsible for the environmental pollution.

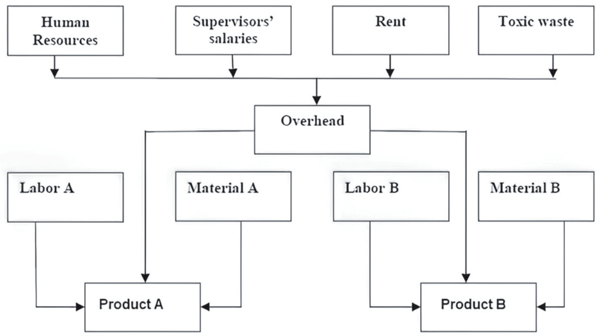
Therefore, the company must identify all environmental costs bases on the classification of environmental costs as it was mentioned.

2.1 Methods of allocation of environmental costs and their comparison

The other serious problem is that the companies use outdated methods of allocation of environmental costs that do not split indirect costs into different groups. The consequence of this solution is like the findings written above.

Figure 1 represents the situation that the company produces two products - "Product A" and the "Product B". "Product A" is the product that is produced without any environmental impact. On the other hand, the production of "Product B" is environmentally harmful, because the company produces harmful toxic waste during its production at the same time. The problem is that the accounting entity knows all its environmental costs that were incurred during a specified period, but these costs were allocated in one group classified as overhead costs. Therefore, the accounting entity allocates all these indirect costs on produced products and does not care if "Product A" or "Product B" is harmful or not.

Figure 1: Incorrect allocation method of environmental costs on produced products

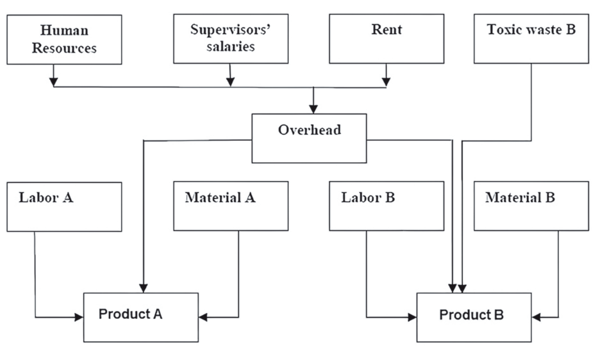


Source: own elaboration (2021)

The second approach shown in Figure 2 is more accurate because the company correctly identified the negative environmental impact caused during the production of "Product B". For this reason, the company directly increases the cost of this product and does not incorrectly increase the cost of "Product A".

This way of environmental costs allocation could cause a crucial impact on the sale of these products because based on the method described in Figure 2 the company reports lower costs of "Product A" and higher costs of "Product B" in comparison with the method shown in Figure 1.

Figure 2: Correct allocation method of environmental costs on produced products



Source: own elaboration (2021)

3. Problem Solution

As we can see, the way of allocation environmental costs is not regulated by legislation, and therefore the accounting entity can choose the system of their allocation itself. If the company wants to achieve the most accurate results, firstly, it is important to responsibly measure and report environmental costs and secondly, to allocate them to the appropriate products.

The comparison of both described methods in the second chapter of this paper can be demonstrated on following the example.

The company operating in the automotive industry needs to find its own cost of production based on absorption costing described by formula (1):

direct costs (material)
+ dicrect costs (wages)
+ other direct costs
+ production overhead costs
own costs of production (1)

Related to the allocation of all overhead costs (environmental and other costs), the company uses the method called overhead rates costing that is described by formula (2):

$$\%\ surcharge = \frac{production\ overhead\ costs}{overhead\ rates\ costing\ base} * 100 \quad (2)$$

We can consider that the analysed company produces 3 products (A, B and C) and uses the total sum of direct material as the overhead rates costing base. The company reported total production overhead cost in the amount of 300,000 EUR (from which 286,000 EUR represent environmental costs incurred only on the production of the product C) and knows the following information about direct cost as shown in Table 1.

Table 1: Direct costs incurred on production

Costs	Product A	Product B	Product C
Direct material (EUR / piece)	55.00	180.00	25.00
Direct wages (EUR / piece)	27.00	32.00	96.00
Other direct costs	20.00	18.00	30.00
Planned quantity of production (pcs)	6,000	3,000	2,200

Source: own elaboration (2022)

The data reported by the analysed company that uses the outdated and incorrect method of allocation of environmental costs on its production are shown in Table 2. All calculations and their results were processed and based on formulas (1) and (2).

Table 2: Incorrect allocation of environmental costs on production based on Figure 1

Costs	Product A	Product B	Product C
Direct material (EUR / piece)	55.00	180.00	25.00
Direct wages (EUR / piece)	27.00	32.00	96.00
Other direct costs	20.00	18.00	30.00

Production overhead costs (EUR / piece)	19.31	50.99	14.16
Own costs of production (EUR)	**121.31**	**280.99**	**165.16**

Source: own elaboration (2022)

The Table 3 represents a situation that the analysed company correctly allocates its environmental costs directly to the products that were produced during the non-ecological production process. All reported results are based on formulas (1) and (2).

Table 3: Correct allocation of environmental costs on production based on Figure 2

Costs	Product A	Product B	Product C
Direct material (EUR / piece)	55.00	180.00	25.00
Direct wages (EUR / piece)	27.00	32.00	96.00
Other direct costs	20.00	18.00	30.00
Production overhead costs (EUR / piece)	0.90	2.38	130.66
Own costs of production (EUR)	**102.90**	**232.38**	**281.66**

Source: own elaboration (2022)

As we can see, the own costs of all products were changed. The comparison of reached results is presented in Table 4. It compares calculated data of own cost of production of all produced products by the accounting entity based on Table 1 and Table 2.

Table 4: Comparison of reported results based on Table 2 and Table 3

Costs	Product A	Product B	Product C
Own cost of production based on Table 1 (EUR / piece)	121.31	280.99	165.16
Own cost of production based on Table 2 (EUR / piece)	102.90	232.38	281.66
Total change in %	**-15.18**	**-17.30**	**+70.54**

Source: own elaboration (2022)

Related to the processed comparison shown in Table 4, the impact of the selected correct method of allocation of environmental costs has significant consequences on the reported own cost of production of all products. We can see that "Product A" and "Product B" are the products produced without ecologically harmful activities.

For this reason, the own cost of production of these products decreased. "Product A" reported a -15.18 % decrease of these costs, and "Product B" was cheaper as well because its own cost of production decreased more than 17 %. On the other hand, we can see that the "Product C" that was produced with harmful impact on the environment increased its own cost of production by +70.54 %.

4. Conclusion

Effective allocation of environmental costs on produced products belongs to one of the important factors that influence the sale of these products. Therefore, when the company uses the optimal method of allocation of indirect costs, the costs are accurately presented in the company's costing system and the consumer pays all direct, indirect costs incurred during the production process. Hence, when the environmental costs dramatically increase the final price of the product, the demand for these products will be decreased. Probably, consumers will prefer more ecological products.

This described system is essential in the automotive industry when the company produces different types of electric vehicles, hybrid vehicles, and vehicles with conventional engines at the same time.

Optimal allocation of all mentioned costs can ensure the lower price of the electric vehicles and, on the other hand, the higher final price of cars with conventional petrol and diesel engines.

Disclosure statement: No potential conflict of interest was reported by the author.

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The Position of the Chinese Electric Car Market in the Global Context

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Abstract

The automotive industry is facing many challenges all over the world. In the medium term, the most crucial task, especially for the EU, is transitioning from internal combustion engines to low-emission drives. This task is part of the global effort to reduce greenhouse gas emissions. The technology connected with battery-electric cars is key to reducing greenhouse gas emissions in the automotive industry.

Developments in recent years have clearly positioned China as a global leader in the field of electromobility. The aim of this paper is to evaluate the current state of the Chinese electric car market and situate it in the context of global production and demand for electric cars. The paper also focuses on Chinese policies aimed at supporting electromobility and expanding domestic electric car manufacturers, as well as recent trends in China's automotive exports.

Keywords: China, automotive industry, electric vehicles, export

JEL Classification: L62, L94, F41, F23, Q56

1. Introduction

The fight against global warming is no longer a concern of the European Union only. In 2015, the parties to the UN Framework Convention on Climate Change signed the Paris Agreement. The Agreement's goal is to keep the growth of average global temperatures significantly below 2° C, and preferably to 1.5° C, compared to the period before the industrial revolution. The Agreement has been ratified by 196 countries of the world, including the EU, the United States, Russia, and China (United Nations, 2022).

The main task in the effort to limit further warming of the Earth is reducing emissions of greenhouse gases. Therefore, individual countries of the world have established dates before which they want to achieve zero net emissions of greenhouse gases. The most-developed countries have committed themselves to achieving so-called carbon neutrality by the year 2050. China wants to reduce its emissions of greenhouse gases to zero by the year 2060, but also to halt the growth of greenhouse gas emissions in its domestic economy by the year 2030 (United Nations, 2022b).

Emissions of greenhouse gases from means of transportation are one of the most important factors in climate change. In the United States and Germany, the share of the transportation sector in overall emissions is about one third. In China, because of its lower level of motorization, transportation contributes about a tenth of overall emissions of greenhouse gases. However, it is predicted that emissions from means of transportation in China will increase until the year 2030 as a result of greater motorization (Li et al., 2016). That is one of the reasons why the government of China introduced measures to support clean means of transport in 2019.

2. Problem Formulation and Methodology

In the past few years the Chinese market for electric vehicles has been growing dynamically. Rapid technological developments, strong domestic demand, generous incentives, and strict regulations, as well as the ambitions of Chinese carmakers, have helped spur demand. This paper will show the development of the market for electric vehicles in China so far, outline future trends, and shed light on the ambitions of Chinese brands for increasing exports to foreign markets.

2.1 Model and Data

To evaluate current developments in the market for electric vehicles in China and confirm China's position as a global leader in the area of electromobility, we must first quantify the trends in the production and sales of electric vehicles on the Chinese market and the share of Chinese production in the global market for EVs. We will enumerate China's share of the world market for EVs in terms of its industry's contribution to electric vehicles in operation. The global ambitions of Chinese producers will be demonstrated by reference to the percentage of China's production of passenger cars that are destined for export.

3. Problem Solution

3.1 China's Goals and Measures to Support Electromobility

The Chinese Ministry of Industry and Information Technology unveiled a plan in 2016 for development of the automobile industry with the title Technology Roadmap for Energy-Saving Vehicles and New Energy Vehicles (GIZ, 2018). New energy vehicles (NEV) include battery electric vehicles (BEVs), fuel cell electric vehicles, and plug-in hybrid electric vehicles (PHEVs). The goal was to increase total production of vehicles in China to 35 million in the year 2025, of which 15 percent should be NEVs. By 2030 the share of NEVs in newly produced vehicles was to increase to 40 percent.

In October 2021 the Chinese government published two documents to assist in the effort to achieve peak greenhouse gas emissions before 2030 and carbon neutrality by 2060. The first is a set of guidelines for the country's climate action and the second is an action plan for achieving the peak in emissions. The action plan includes support for low-emission transportation, such that the share of new energy vehicles in total new sales will be about 40 percent by 2030 and the carbon emission intensity of commercial vehicles will decline by about 9.5 percent in 2030 compared to 2020. According to the action plan, a large part of the government's support will be allocated to development of charging and refueling infrastructure (News.cn, 2021).

The government of China is attempting to achieve its goals using various instruments, the most important of which are subsidies for the purchase of new NEVs and requirements placed on the producers of automobiles. The following table is a brief overview of China's measures for supporting electromobility.

Table 1: Measures of the Chinese Government to Support New Energy Vehicles

Type of Measure	Measure	Description
Financial Measures for Citizens	**Tax Exemptions for Acquisition of Vehicles**	China's vehicle purchase tax is 10 percent of the price of the vehicle before value-added tax for domestically produced vehicles and 10 percent of the price of imported vehicles. China's Ministry of Industry and Information Technology has issued an "NEV Catalogue," a list of automobiles that are eligible for exemption from the purchase tax. Currently the exemptions from tax are in place to the end of 2022, but it is expected that they will be extended (CnEVPost, 2022).
	Subsides for Vehicle Purchases	The main incentive for purchase of electric vehicles in China since 2009 has been government subsidies for purchase of electric vehicles. These can amount to RMB 66,000 (EUR 9,000). They have been reduced in the last few years. For 2021 they were reduced to RMB 14,400 (EUR 2,000), for 2022 by another 30 percent, and they will be phased out entirely by the end of 2022 (Zhang et al., 2021).
Non-Financial Measures for Vehicle Operators	**Special License Plates**	The chance of obtaining a license plate in many Chinese cities through the traditional lottery system is very low. From 2016, China has begun to issue "green" license plates for NEVs, for which the probability of obtaining one is much higher. (Argus, 2021)
	Prohibitions on Entry of Vehicles into Cities	Cars with internal combustion engines are prohibited from entering the centers of some cities on days when air pollution is high. This prohibition does not apply to NEVs.
Require-ments for Vehicle Manufac-turers	**Corporate Average Fuel Consumption (CAFC)**	The main goal of CAFC regulations is to support energy-saving technology and reduce the consumption of fuels. If a manufacturer of autos on the Chinese market exceeds imposed weight-based fleet consumption limits they can be fined.
	CAFC and NEV Credits	According to the so-called Dual-Credit Regulation, CAFC credits are given based on corporate average fuel consumption and target values. The target value for a car manufacturer is the average target value of all vehicles, which is based on the industry segment the vehicle belongs to. The NEV credit for a manufacturer is the difference between its total NEV credits and its target value for NEVs. CAFC and NEV points are tradeable. Fines are imposed on manufacturers who end the year with negative points. (Ye et al., 2021)
	NEV Manufacturing Licences	Companies that want to manufacture NEVs in China must obtain production and sales authorizations from the National Development and Reform Commission and the Ministry of Industry and Information Technology.

Source: GIZ: The E-Mobility Race and China's Determination to Win

Besides the incentives and regulations listed above, the Chinese government provides support to some Chinese manufacturers of electric vehicles. The central and local governments directly sponsor the building of new factories and R&D centers, foreign acquisitions, and exports of products to the global market (Mercator Institute for China Studies, 2021).

3.2 Electric Car Sales in China and Worldwide

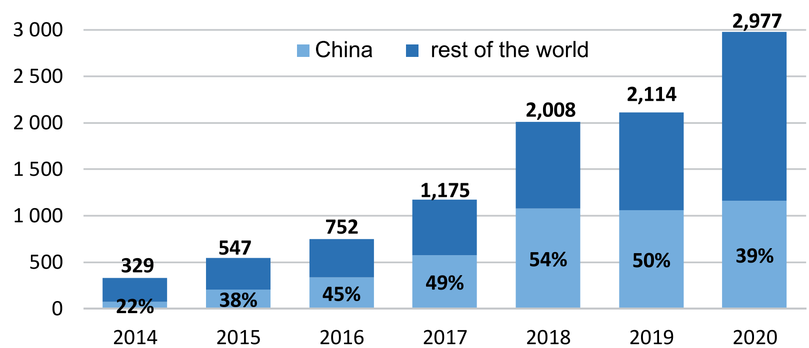
Most of the growth in electromobility in the world has come after the year 2015. In 2010 only 8,200 electric vehicles (including battery electric vehicles and plug-in hybrid electric vehicles) were sold worldwide, of which 1,400 were sold in China (17 percent of world sales). In 2014 more than 250,000 electric vehicles (EVs) were sold worldwide, of which 22 percent were sold in China. China has quickly become a large part of the market for new electric vehicles. In 2017, when global sales of EVs exceeded one million vehicles (1,174,644), China approached a 50 percent share with sales of 579,000 EVs. The rapid growth in worldwide sales of EVs increased the total number of electric vehicles in operation. In 2015 their number exceeded one million, of which a quarter were in use in China.

In 2018 China again achieved the highest share (54 percent) of total sales of electric vehicles in the world. Since then that share has slightly declined. As the absolute number of EVs sold in China has increased, so has their share in the number of personal automobiles sold. In 2018 the share of EVs in the total sales of personal automobiles in China increased to 4.6 percent, compared to the world average of 2.5 percent. The latest figures available are for 2020, when almost the entire world was affected by the COVID-19 pandemic. The year 2020 was marked by a very rapid drop in production worldwide as the pandemic closed production plants for several weeks.

As the supply of electric and hybrid cars increases, so does the demand for them, and the number of such vehicles sold worldwide is rapidly growing. This has been facilitated by tighter limits on emissions which carmakers in some parts of the world (including the EU) are required to meet (*Šaroch et al.*, 2021). Sales of EVs increased more than 40 percent in the first half of 2020, or by almost three million cars. However, sales of new EVs in China grew only about 10 percent, and the share of electric vehicles sold in China declined to only 39 percent of world sales. The timeline of the pandemic in China was different from that of other regions because of its earlier outbreak there. The total number of new registrations of automobiles decreased by about 9 percent in 2020. In the first half of 2020 new registrations of EVs in China showed a smaller increase than that of the entire automotive market. However, in the second half of the year, when the coronavirus crisis began to subside, this trend reversed. Thus, the share of EVs in overall sales for all of 2020 grew by 5.7%, which amounted to almost 1 percentage point more than in the previous year, when that share was 4.8 percent. Worldwide in 2020 there was a significant increase in the share of EVs in overall car sales, to 4.6 percent from 2.7 percent in 2019.

According to information from the International Energy Agency (IEA), in the next ten years the pace of sales of electric vehicles will greatly increase. It is projected that in 2025, 4.5 million EVs will be sold in China alone, which will be 40 percent of the estimated 11.3 million electric vehicles sold in the world. The share of EVs in the total sales of automobiles will increase to 20.1 percent in China, and in the world to 10.4 percent. In its outlook, the IEA estimates that 22.1 million new electric vehicles will be sold in the world in 2030 (*Šaroch et al.*, 2020). In China it will be nearly nine million, which will be 40 percent of global sales. Electric vehicles are expected to constitute 33.8 percent of total sales of automobiles in China in 2030, while in the world that percentage will reach an average of 17.3 percent.

Figure 1: Electric Vehicle Sales Worldwide (in Thousands of Units) and China's Share of World Sales



Source: IEA; EVs refers to all electric vehicles (BEVs + PHEVs)

Table 2: Electric Vehicle Sales Outlook (in Thousands of Units)

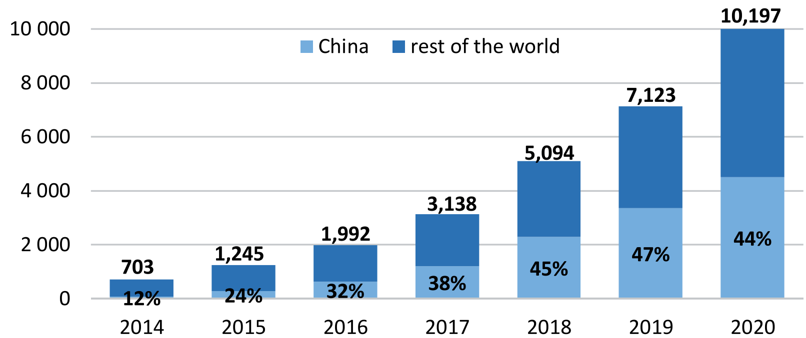
	2020	2025*	2030*
China	**1,160**	**4,548**	**8,937**
World	2,977	11,341	22,132
China's Share of Global EV Sales	39.0%	40.1%	40.4%
China: Share of EV Sales in Total Domestic Car Sales	5.7%	20.1%	33.8%
World: Share of EV Sales in Total Worldwide Car Sales	4.6%	10.4%	17.3%

*Source: IEA; EVs refers to all electric vehicles (BEVs + PHEVs); STEPS scenario; * forecast*

3.3 The Stock of Electric Vehicles in China and Worldwide

The absolute number of electric vehicles on the road is increasing along with the intensive growth in their sales. In 2020 the number of EVs worldwide exceeded ten million, of which 4.5 million were in China, about 44 percent of the total. The number of EVs on the road in 2020 was not even 1 percent of the total number of personal automobiles in the world, which was approaching 1.1 billion. In China, EVs were 1.7 percent of the national total. According to estimates by the IEA, 45.9 million electric vehicles will be in use worldwide in 2025. Those vehicles will represent 3.2 percent of a projected 1.4 billion personal automobiles in the world. In China, the rapid growth of electromobility means there will be more than 20.3 million EVs in operation in 2025, which would be 6.2 percent of the overall number of automobiles in service. That share is expected to more than double in the following five years to 13.2 percent (52 million EVs!). By the year 2030, 42 percent of the expected total of 124.3 million EVs in the world will be in service in China.

Figure 2: Electric Vehicle Stock Worldwide (in Thousands of Units) and China's Share of Worldwide Stock



Source: IEA; EVs refers to all electric vehicles (BEVs + PHEVs)

Table 3: Electric Vehicle Stock Forecast (in Thousands of Units)

	2020	2025*	2030*
China	**4,509**	**20,366**	**52,054**
World	10,197	45,963	124,332
China: Share of World EV Stock	44.2%	44.3%	41.9%
China: Share of EVs in Domestic Stock of Cars	1.7%	6.2%	13.2%
World: Share of EVs in World Stock of Cars	0.9%	3.2%	7.5%

*Source: IEA; EVs refers to all electric vehicles (BEVs + PHEVs); STEPS scenario; * forecast*

3.4 Electric Vehicle Production in China

The production of electric vehicles in China has grown about seven times since 2016. In 2016, 516,000 EVs were produced in China. In 2021 that number exceeded 3.5 million. Production of fully electric (battery electric) vehicles (BEVs) was 2,942,000 in 2021, which represented a year-on-year increase of 170 percent. Also in that year, China produced 601,000 plug-in hybrid vehicles (PHVs) (a year-on-year increase of 130 percent) and 2,000 fuel cell vehicles (FCVs).

Table 4: Elecric Vehicle Production in China (in Thousands of Units)

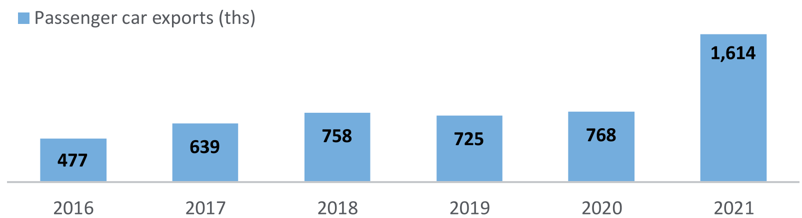
	2016	2017	2018	2019	2020	2021
EV Production	516	794	1,270	1,242	1,366	3,545

Source: MarkLines. all electric motor vehicles

3.5 China's Automotive Exports (Are Trending Upwards)

China is confirming its growing position in automobile exports as well. While in 2016, 477,000 of the passenger cars produced there were exported, in 2020 that number increased to 768,000. The year 2021 saw year-on-year growth in China's exports of personal automobiles of 110 percent, to a total of 1,640,000 cars.

Figure 3: China's Passenger Car Exports (in Thousands)

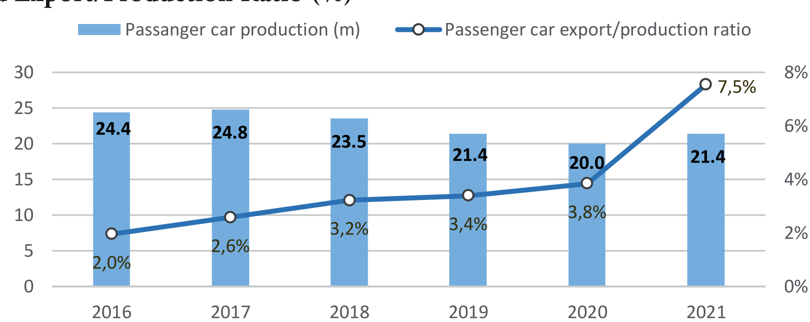


Source: MarkLines, CAAM

The share of exports in the total production of passenger cars in China has grown by more than 300 percent since 2016. In 2016 that share was 2 percent, while in 2020 it was 3.8 percent. In 2021 however, the share of passenger cars destined for export from China was 7.5 percent of total production.

Electric vehicles must be counted in the production numbers, but information on exports of EVs from China is available only from 2021. The total number of electric passenger vehicles produced in China that year was 3,359,000 units. Of that total, 296,000, or 8.8 percent, were destined for export. The share of electric vehicles in exports from China of passenger cars of all kinds was 18.3 percent.

Figure 4: China Passenger Car Production (Thousands) and Export/Production Ratio (%)



Source: MarkLines, CAAM

The plans of China's domestic producers of EVs for export of their models to Europe indicate an intention to dominate the market for EV's there. According to statistics published by the MERICS Institute, 63 percent of China's exports of electric vehicles (totaling 65,261 units) were sent to six European countries: Belgium (17 percent), the United Kingdom (13 percent), Germany (9 percent), Norway (9 percent), Netherlands (8 percent), and Sweden (7 percent).

Table 5: Chinese Electric Vehicle Makers Ramp Up Export Plans for Europe

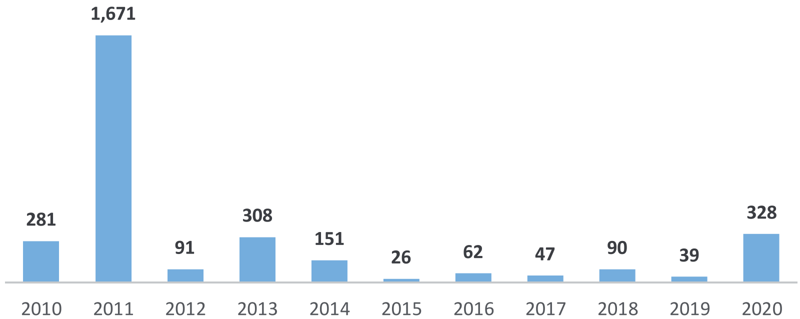
Carmaker	Ownership	EV models	Export start
Maxus (SAIC)	SOE	e0eliver3; EV80	February 2018
Chery	Private	Exeed	October 2018
Zhi Dou	Private	02S	June 2019
JAC	Private	E-S2	August 2019
MG (SAIC)	SOE	MG ZS EV; MG RX6	September 2019
Aiways	Private	US	May 2020
SUDA	Private	SAOl	May 2020
Tropos	Private	Able XT 1/2	August 2020
Xpeng	Private	G3i	September 2020
DSFK	SOE	SERES	October 2020
Dorcen	Private	FINN/LEO	October 2020
Weltmeister (WM Motor)	Private	EXS	November 2020
Great Wall Motor	Private	Wey	April 2021
BYD	Private	Tang[1)]	May 2021
NIO	Private	ES8	May 2021
Skywell	Private	ETS/BEO	July 2021
Byton	Private	M-Byte	2022[2)]
Geely	Private	Zeekr	2023[3)]

Source: MERICS; [1)] BYD also manufactures electric buses in Europe and also exports them to Europe; [2)] June 2020: Byton suspends operations due to virus; [3)] Announced

3.6 Share of Chinese Passenger Cars Registered in Europe (Is Still Low)

While the steep rise in China's production of electric vehicles and the increasing share of exports in its domestic production is obvious, there is no evidence of Chinese dominance in the number of new cars registered in Europe. The share of registrations of Chinese-produced cars in the countries of Western Europe (EU14+EFTA+UK) is still low (328 units in 2020, or 0.003 percent of total passenger car registrations).

Figure 5: Chinese Manufacturers Passenger Cars New Registrations in Western Europe (EU14 + EFTA + UK)



Source: ACEA

4. Conclusion

The Chinese market for electric vehicles has boomed in the past few years. China's production and sales of EVs, and the number of EVs in operation, are now not quite half of the corresponding total worldwide figures. Government incentives for acquisition of "new energy vehicles," as well as rather strict requirements placed on carmakers in China, have had an influence on that trend. In the last two to three years the Chinese government and domestic car brands have put an emphasis on exporting personal cars onto the world market. In 2021, 7.5 percent of China's total passenger car production was destined for export. Almost one fifth of those vehicles were EVs. However, new registrations of Chinese automobile brands in Europe are still no more than 0.003 percent of total new car registrations there. Nevertheless, it will be necessary to be aware of the development and global ambitions of Chinese carmakers.

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The Use of The DNN YOLO Architecture in The Analysis of Transport Operations in Intralogistics Process – Case Study

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Abstract

Popularization of deep neural networks in image classification and object detection, combined with common image recording measures in an industrial environment, create space for application research in the field of improvement and reduction of data acquisition costs for intralogistics operations. This paper presents the results of research on the application of the object detection architecture from the YOLO group (You Only Look Once) in the analysis of transport performance of intralogistics system, operating with full-pallet loads. The paper contains a detailed description of the developed solution, an estimate of the efficiency of the solution with the use of commercial computers, and an assessment of the observer's influence on the measurement result for the presented solution and classic methods of mapping transport operations in intralogistics. The purpose of this paper is to indicate the application utility of the presented solution in the internal supply chain, for the transportation system in the plant of an automotive supplier.

Keywords: dnn, intralogistics, object detection, transfer learning

JEL Classification: C810, C880, L620, L900

1. Introduction

The development of modern intralogistics, based on the Industry 4.0 concept, challenges the interdisciplinary scientific approach in the analysis and description of logistic processes. The market position of companies is now not only based on the development of new products and their distribution, but also on the improvement of processes in external and internal supply chains using modern digital tools. Optimization of internal procurement and planning processes through process reorganization is a key element to improve the competitiveness of companies. Modern development of intralogistics 4.0 requires simultaneous production and storage infrastructure, transport and storage techniques and technologies and information support based on material flows of the company (Rosi & Lerher, 2017). The idea of Industry 4.0 assumes the interdependence of people, machines, products and systems at the level of management and information processing. The Industry 4.0 model assumes that these units are intelligent objects capable of independent management and communication with the environment. Thanks to this it is possible to develop a model of virtual reality, which reflects the processes conducted within the system (Radivojević & Milosavljević, 2019). The main elements of Industry 4.0 are Big Data and Analytics, Autonomous Robots, Simulation, Horizontal and Vertical System Integration, The Industrial Internet of Things, Cloud Computing, Additive Manufacturing, Augmented Reality and Cyber Security (Erboz, 2017). The described assumptions and Industry 4.0 elements are based on the acquisition and subsequent processing of large amounts of data, which should be of the highest possible quality. The collection of such data for logistics processes in the process improvement phases is time-consuming and costly. The fourth industrial revolution can be difficult to implement for small and medium-sized companies due to the costs for data acquisition and post-processing. In this article, we discuss a deep neural network with transfer learning approach that reduces implementation costs to a minimum. Observation of the functioning intralogistics system in order to improve it requires long-term actions involving many resources. Using classical methods of process evaluation, it is difficult to obtain satisfactory results of current process efficiency monitoring. Activities requiring the involvement of engineering personnel in the ongoing analysis of the process in modern business conditions, are necessary to ensure the intellectual resources of the organization for the generation of competitive advantage.

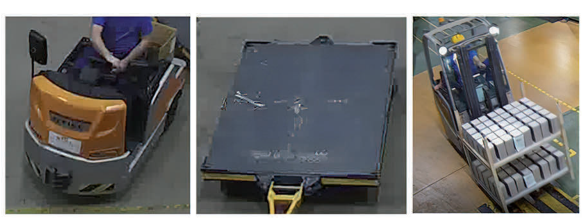
The following sections of the paper will present a case study of analysis of the possibility of improving the internal distribution process based on the classical logistic train using trained neural networks in the YOLO3 architecture fed with CCTV images.

2. Problem Formulation and Methodology

2.1 Problem Formulation

The case in paper concerns the detection of 3 classes of objects identified on the basis of camera images with a resolution of 1920 by 1080 pixels. The first 2 objects shown in Figure 1 represent a logistics train and a platform, while the 3rd one is a forklift carrying battery electrodes without the required protection. The research problem was the correct and real-time detection of the described objects. With correct detection, it is possible to develop solutions to continuously analyse the efficiency of a transport system based on non-autonomous means of transport in internal logistics, without the need to invest in additional infrastructure to collect data on the location and occupancy of means of transport. In addition, a solution not integrated with other IT systems allows to bypass unfavourable legal regulations requiring the payment of fixed integration fees.

Figure 1: Case study class object examples



Source: Own elaboration

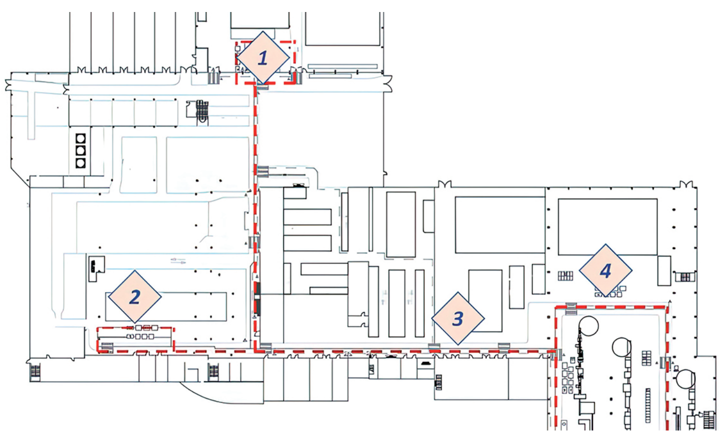
The main features of the system are listed below:

1. Correct classification of objects belonging to 3 classes: ['milkrun', 'empty_platform', 'plate_forklift'].
2. Probability for class detection > 70%.
3. Object bounding box is secondary due to no practical use of precise bounding box in application – intersection over union >= 0.5.
4. Detection results saved in folder for verification.
5. Video processing with 2–5x real time speed.
6. Detection results allow to create a map of realized routes and deviations from the loop initiation frequency.
7. Use of 15 CCTV cameras as data source.
8. The sequence of detection of the 'milkrun' object on individual cameras defines the executed route.

The routines analyzed by the software are shown in Figure 2. Three routines are defined:

1. 1<-> 4 ; WAREHOUSE <-> ASSEMBLY
2. 1-3-4 ; WAREHOUSE – FORMATION – ASSEMBLY
2. 2 <-> 4 ; BATTERY ELECTRODES WAREHOUSE – ASSEMBLY

Figure 2: Plant layout with routine points

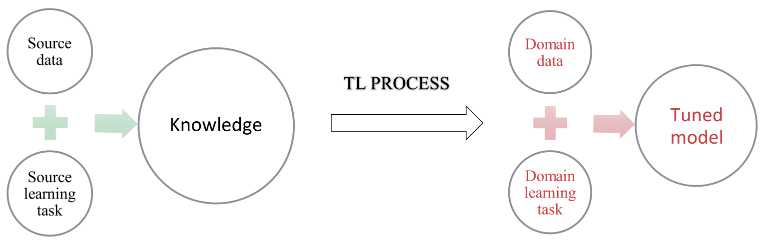


Source: Own elaboration

2.2 Transfer Learning

Deep learning algorithms try to learn high-level features from large amounts of data, putting it ahead of typical machine learning. It uses a hierarchical feature extraction technique with an unsupervised or semi-supervised feature learning approach to extract data features automatically. Traditional machine learning methods, on the other hand, necessitate manually designing features, which places a significant burden on users. Deep learning can be defined as a machine learning representation learning algorithm based on large-scale data. Transfer learning (TL) is an optimization stage that allows rapid progress or improved performance when modelling the second task. Transfer learning is a machine learning (ML) research problem that focuses on solving one problem, preserving the knowledge gained, and applying it to another related problem. Figure 3 presents the basic diagram of transfer learning (Tan *et al.*, 2018).

Figure 3: Transfer learning diagram



Source: Own elaboration

The basic aim of the implementation was to minimize financial outlays in reduction of infrastructural and personnel costs. Therefore, the implementation activities were based on deep transfer learning methods from pretrained convolutional networks because of the sparse representation of objects that could be used in training the network from scratch

In the documentation of the Keras library, we can find the basic definition of the next stages of the TL process. The stages are described below:

1. Obtaining the weights of the model from the network trained on correlated data.
2. Freezing weights for layers containing feature generalization to avoid weight recalculation in the process of training a new network.
3. Adding new layers on top aimed at correct representation of the model output data.
4. Training model in domain dataset.
5. Unfreezing of selected layers in order to achieve a better match of weights to new data(optional step) (Chollet, 2020).

As described above, the use of TL methods is not a complicated task, and in tasks with correlated data it can significantly reduce the time of prototyping or implementing unique solutions.

2.3 YOLO3 Architecture Implementation

The technique of detecting the recognizing, area, and class of at least one object within an image is known as object detection. Every individual object in the image is labelled as a class object by the detection method, which forms a bounding box around them. YOLO is an object detection approach that use a deep convolutional neural network (Menon, Omman & Asha 2021). YOLO is a deep learning-based single-shot object detection approach formed in 2016. The term "one-shot detection" refers to the extraction and classification of features in a single step. Other object detection algorithms, such as RCNN, Faster R-CNN, and others, construct probable bounding boxes in an image before running a classifier on them.

YOLO v3 uses an architecture of Darknet-53 new neural network for performing feature extraction based on 53 convolutional layers. YOLO v3 makes over scale predictions; it uses three different scales. Prediction over three unique scales for all positions of the input image is the most powerful feature of YOLO v3. System predicts the same way as feature pyramid network, FPN, does. A boundary box, objectness, and class score are all used to make each prediction (Menon, Omman & Asha 2021). The loss function for YOLO v3 in equation (1) is sum of squared error (SSE) loss of

$$\begin{aligned} &\lambda_{\text{coord}} \sum_{i=0}^{S^2} \sum_{j=0}^{B} \mathbb{1}_{ij}^{obj} [(x_i - \hat{x}_i)^2 + (y_i - \hat{y}_i)^2] \\ &+ \lambda_{\text{coord}} \sum_{i=0}^{S^2} \sum_{j=0}^{B} \mathbb{1}_{ij}^{obj} \left[\left(\sqrt{w_i} - \sqrt{\hat{w}_i}\right)^2 + \left(\sqrt{h_i} - \sqrt{\hat{h}_i}\right)^2 \right] \\ &+ \sum_{i=0}^{S^2} \sum_{j=0}^{B} \mathbb{1}_{ij}^{obj} \left(C_i - \hat{C}_i\right)^2 + \lambda_{\text{noobj}} \sum_{i=0}^{S^2} \sum_{j=0}^{B} \mathbb{1}_{ij}^{noobj} \left(C_i - \hat{C}_i\right)^2 \\ &+ \sum_{i=0}^{S^2} \mathbb{1}_{i}^{obj} \sum_{c \in \text{classes}} \left(p_i(c) - \hat{p}_i(c)\right)^2 \end{aligned} \qquad \textbf{(1)}$$

where:

$\mathbb{1}_{i}^{obj} = 1$ if an object appears in cell i, otherwise 0.

$\hat{p}_i(c)$ denotes the conditional class probability for class c in cell i.

$\mathbb{1}_{ij}^{obj} = 1$ if the j th boundary box in cell i is responsible for detecting the object, otherwise 0.

λ_{coord} increase the weight for the loss in the boundary box coordinates.

$\hat{C}_i$ is the box confidence score of the box j in cell i.

$\mathbb{1}_{ij}^{obj} = 1$ if the j th boundary box in cell i is responsible for detecting the object, otherwise 0.

$\mathbb{1}_{ij}^{noobj}$ is the complement of $\mathbb{1}_{ij}^{obj}$.

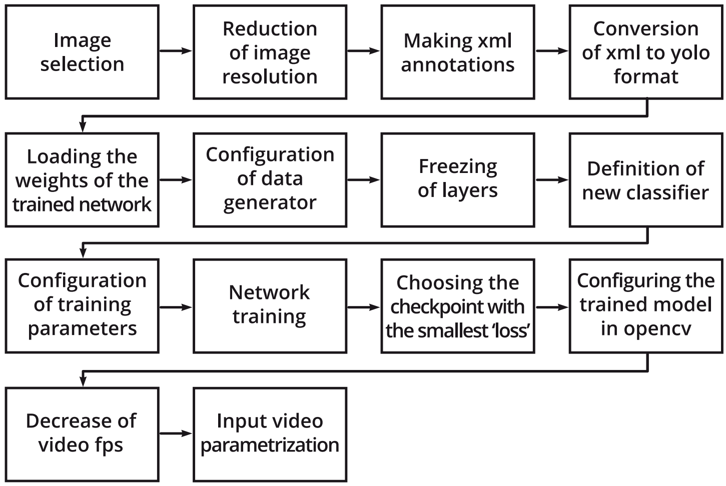
$\hat{C}_i$ is the box confidence score of the box j in cell i.

λ_{noobj} weights down the loss when detecting background.

regression, confidence, and classification loss (Redmon *et al.*, 2016).

Taking into account the above, with the use of free tools, the implementation of the architecture presented in Figure 4 was carried out using 2204 picture dataset.

Figure 4: Architecture implementation scheme



Source: Own elaboration

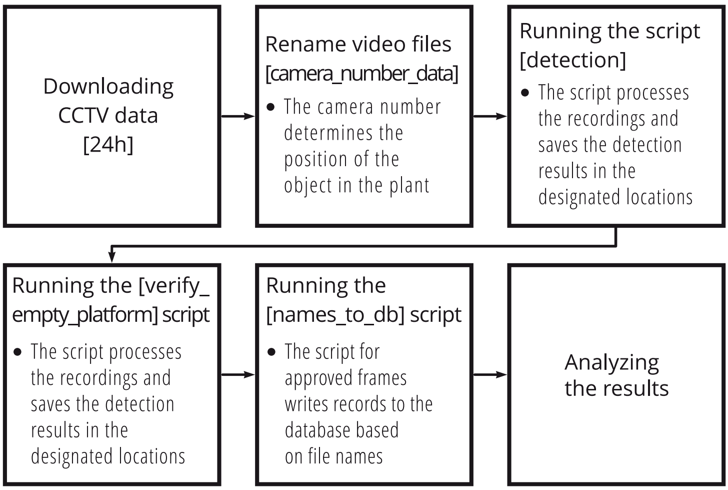
Described architecture implementation steps are complete and allows to train new classifier in less than 3 hours using CUDA® computing with GeForce® GTX 1650Ti. One of the key stages of implementation is the annotations in xml format and their subsequent conversion to YOLO format. Thanks to this, in case of insufficient results with YOLO, it is possible to use annotations in other architectures. After configuring the data generator, all layers of the model were frozen and at the same time the classifier trained on the UA-DETRAC dataset was removed. As configuration we use Keras RMSprop optimizer with learning rate = 2e-5, batch_size = 10 and epochs = 100. After training, the checkpoint with the least error was selected and implemented in OpenCV. Due to the high framerate in the input video and hardware limitations, decreasing of frame rate was also necessary. Completion of these steps allowed for the production implementation of the model with satisfactory efficiency.

3. Problem Solution

The research was carried out using a commercial computer with a ninth generation Intel® Core i7 processor and a GeForce® GTX 1650Ti graphic card. As the development environment were used PyCharm, Keras library – in which the YOLO v3 network architecture was developed and the Django framework, in which the Web application was implemented. Application data is stored in PostgreSQL database, and annotations were made in the LabelImg application. As of the date of this article, all the mentioned applications are free of charge and allow for own implementation of the presented solution.

The software design requirements outlined above directly influenced the conceptual scheme of the computer system designed to analyse transportation operations using object detection. Recording frames with the detection performed from the processed monitoring recordings allows for quick verification of the correctness of the algorithm and supplementing the input data set with examples of class objects that were not correctly identified by the deep network.

Figure 5: Analyse process diagram



Source: Own elaboration

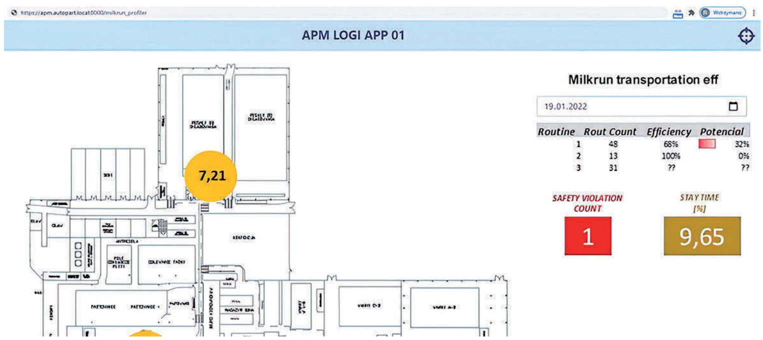
The premise of the application is to save frames so that the correctness of the model can be analysed. In case of missing detections, it is possible to copy the image for annotation, which is used to improve the quality of the trained model. Example frames containing incomplete detections are shown in Figure 6. on the left side of the example, the model in development failed to identify 2 empty platforms in the frame. Therefore, in the initial phase of using the software for transportation work analysis, it was assumed that the frames with detections for the 'empty platform' class present an inefficiency of the transportation set of 50%.

Figure 6: Sample frames saved by application

Source: Own elaboration

Figure 7 shows a screenshot of a web application that indicates a summary of transportation system efficiency on a particular day. In the case in question, the potential of the transport set is indicated in the form of the percentage of empty platforms during the implemented operations. In addition, the application indicates the percentage of time during which the transport set carried out transport work in excess of the norm for the operation. In the red square there are safety risks defined on the basis of the sequence of the transport set appearance in the place not matching the defined sequences of routes.

Figure 7: Final web application screen shot



Source: Own elaboration

4. Conclusion

The presented solution has been implemented in AUTOPART battery plant located in Poland, the supplier of starter batteries for vehicles. In our opinion, the solution can be widely used in industry. Not only in automotive sector, but everywhere where there are events recording devices available in production area and there are repetitive routines of internal transport. The use of transfer learning methods allows to significantly shorten the process implementation of deep learning solutions. Classical machine learning methods require much more expertise than the deep methods cited in the paper. Applications based on deep learning using an appropriate degree of generalization allow to achieve high computational efficiency and versatility of solutions that can be used in other applications after minor modifications to the size of input vectors or network output layers. The project presented in the report is a good example confirming the effectiveness and ease of using pre-trained networks in industrial/commercial applications. The project achieved an SSE of 140 which is a satisfactory result. In addition, the time required to perform the analysis for a single day was reduced by nearly 93% which allows for continuous analysis rather than taking a snapshot of a day as before. Additionally, the observer's influence on the results was eliminated. No potential for improvement was seen with the classical methods. On the other hand, with continuous observation using YOLO, nearly 30% potential to use the transport means for other purposes became apparent. Errors in data collection are minimized to zero. What remains to be improved is the frame processing speed (7 frames per second using commercial PC), which is not sufficient. As a countermeasure the number of frames per second was reduced, which allows to process data at a satisfactory rate. The possibility of implementing additional conditions should be noted. In the presented case, the logic of the program allows not only to analyze the routes but also to define the threats or incompatibilities related to safety. This, in turn, allows to reduce the operational risk of processes, by continuous monitoring of violations without the suspicion of continuous monitoring review. The algorithm registers only selected types of events and does not affect the sense of freedom of employees, after using appropriate communication. Transfer learning opens the door for users to share knowledge and achievements in general machine learning disciplines which is crucial for minimizing work and improving quality in today's economy.

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Tram Gearbox Optimization in order to reduce Noise Emission

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Abstract

The first part of this paper deals with optimization steps on the tram gearbox in order to reduce noise emission. The company Wikov MGI, within the project TAČR CKVD, has run experimental noise measuring on geometry and micro-geometry of helical gears. The results of those experimental measurements were used to reduce excitation from the gear mesh frequency. The second part of the paper deals with optimization of the gearbox as with a complex kinematic dynamic and acoustic model. This was done with help of the software Romax by the company Hexagon. This approach of the prediction of noise emitted from gearbox surfaces focuses on the noise caused by the gear mesh excitation which is further transmitted through the gearbox to its housing. The authors verified those methods on a gearbox prototype using test equipment. The prototype was custom-built for this purpose.

Keywords: reduction of noise, geometry and micro-geometry of helical gears, noise emitting

JEL Classification: Z

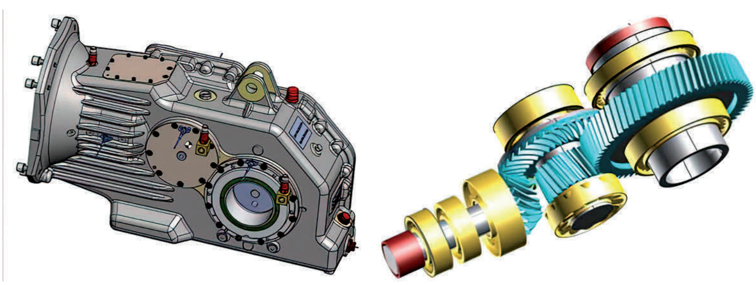
1. Introduction

At present, there are more and more demands to reduce the noise emission of rolling stock gearboxes, but at the same time, there are also demands to reduce the weight of gearboxes to reduce energy consumption. Both of these requirements for rolling stock must not have the effect of reducing the required service life of a component such as a gearbox. Reducing noise emissions is a complex process that starts with reducing excitation sources, where the main source is the gear mesh frequency and harmonics. This excitation can be further amplified by various resonance frequencies, which can occur both in the torsional system, where are the rotating components of the transmission, and on the housing of the gearbox. There are also cases when the excitation from the gears is transferred to other components of the rolling stock chassis. Nowadays, not only the total sound pressure level or acoustic power in the entire speed range of the gearbox operating speed but also the tonality is limited in the technical specifications according to which the gearbox design is processed. All these requirements can only be met if both of these conditions are fulfilled. Firstly, attention must be paid to the detailed optimization of the macro-geometry and micro-geometry of the gears. Secondly, the designer can control the resonance of the torsional system as well as the gearbox housing. The use of comprehensive Romax gearbox design software allows Wikov MGI to meet these requirements. Over the past five years, Wikov MGI has focused primarily on optimizing helical gears to reduce noise emissions through an extensive DOE full factorial experiment that tested 81 combinations of different gear micro-geometries. However, the transmission that will be optimized later in this article is a two-stage system. The first gear pair at the input is a bevel gear and the second gear is helical. We have not optimized noise reduction for Klingenberg bevel gears in the past, so we decided to work with Hexagon to design a new type of gearbox, which uses the appropriate Romax software, which can also include the results of bevel gear micro-geometry optimization from special KIMoS software for production. Furthermore, the optimal distribution of resonance areas with respect to operating modes and prescribed tonality was solved in this software.

1.1 Description of the gearbox

It is a two-stage bevel gearbox with a gear ratio of 6.78 (Fig.1), where the first gear is realized by a Klingenberg bevel gear with a maximum input speed of 4200rpm. The maximum torque on the input shaft is 1050Nm. The second output stage is the helical gear. The gearbox is firmly connected to the motor housing and a membrane coupling connects the shafts. The gearbox is connected to the axle by a flexible coupling. The gearbox and motor housing are connected to the chassis with three silent blocks.

Figure 1: Tram gearbox and torsional structure



Source: Wikov Design of gearbox (2021)

2. Helical gear micro-geometry optimization

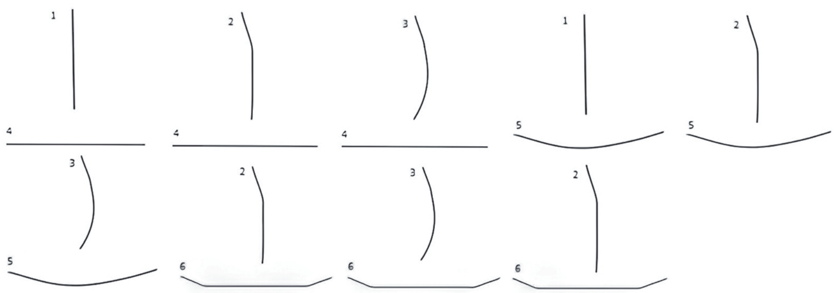
As part of its systematic work to reduce the acoustic emission of gearboxes, the Wikov MGI company has focused in recent years on optimizing the micro-geometry of gears thanks to the TAČR CKVD research program [2]. The effect of gear geometry itself has been elaborated in detail at FZG Munich [4] and can be very well drawn from the research materials. As far as the micro-geometry of the gears is concerned, this is a more complex task, as it is necessary to focus not only on the reduction of noise emission but also on the guaranteed service life of the gears when designing the micro-geometry. The following parameters must be considered for the correct design of gear micro-geometry [1]:

1. Deflection of the teeth.
2. Bending and Torsion of the shafts

3. Stiffness of the bearings
4. Clearance into the bearings
5. Stiffness of the gearbox housing in the area of bearings

All these parameters can be included in the gear calculation in the Kisssoft software available to Wikov MGI. Thanks to these possibilities, an experimental design was performed with nine different modifications of pinion teeth and nine different modifications of gear teeth. All basic shapes of micro-geometries can be seen in Figure 2. In terms of shape, the micro-geometries are the same for both the pinion and the wheel. Using the Full Factorial tool in the Design-Expert software, 81 combinations for real noise measurements were designed in various steps.

Figure 2: Micro-geometry



1. without profile modification
2. tip relief
3. envelope barrelling
4. without lead modification
5. crowning
6. end relief

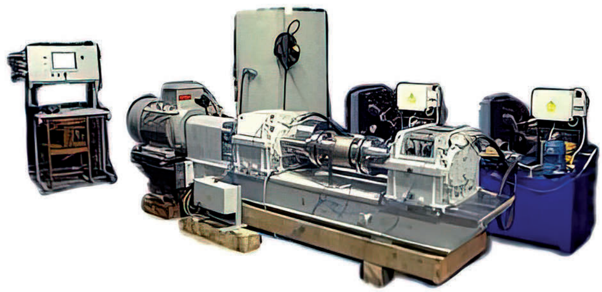
Source: own elaboration (2019), reference paper [2]

All designed micro-geometries and basic gear geometry have been optimized for a specific load that corresponds approximately to rolling stock applications. Figure 3 shows a sample of gear pair and Figure 4 shows an available test stand in Wikov company. The A-weighted sound pressure level was measured using a Pulse device from Brüel & Kjær at a distance of 1 m from the largest face of the gearbox.

Figure 3: Test sample of gear pair

Source: own elaboration (2019), reference paper [2]

Figure 4: Testing equipment



Source: own elaboration (2019)

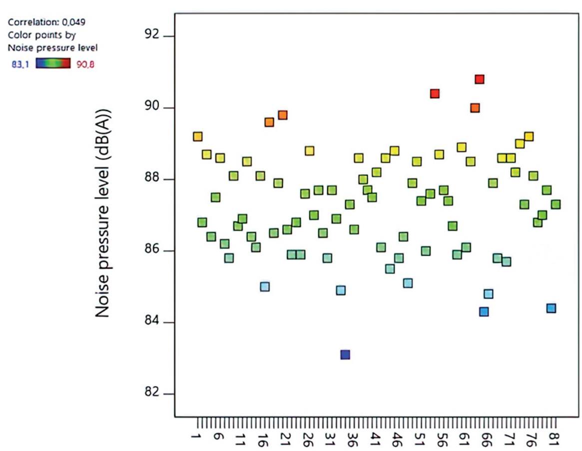
2.1 Experiment with help of DOE tools

The experiment used the Full Factorial tool, which was designed for 4 parameters with three set levels. The parameters are as follows:

A. Profile micro-geometry on the pinion,
B. Lead micro-geometry on the pinion,
C. Profile micro-geometry on the gear wheel,
D. Lead micro-geometry on the gear wheel

The set levels are always micro-geometry shapes according to Figure 2.

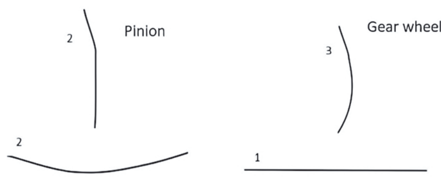
Figure 5: Results of the acoustic pressure level



Source: own elaboration (2019), reference paper [2]

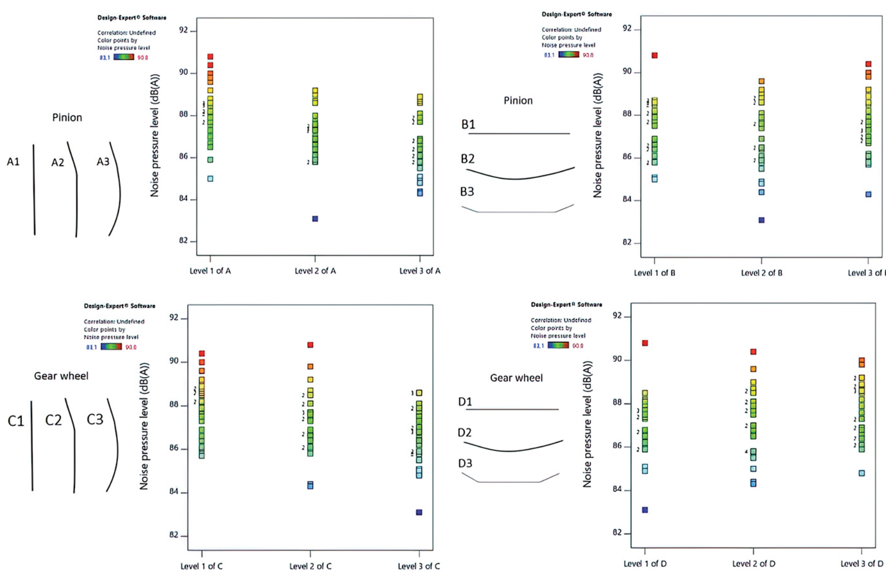
Figure 5 shows the sound pressure level results for all combinations. It can be seen from this graph that the difference in sound pressure level between the best and the worst result is 7.7dB. To analyse the influence of individual parameters on the result, the individual level settings for the given parameters can be seen in Figure 7. The results show individual sensitivities to the given parameters and their level settings. The best combination of micro-geometry is shown in Figure 6.

Figure 6: The best result of the micro-geometry



Source: own elaboration (2019), reference paper [2]

Figure 7: Results for detailed parameters

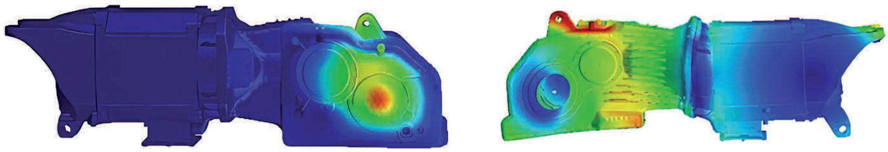


Source: own elaboration (2019), reference paper [2]

3. NVH and acoustic prediction

The knowledge of the housing's modal shapes, including the harmonic response excitation, is a vital part of a comprehensive solution to reduce the noise emission of the gearbox. Calculations of mode shapes, including the response to frequency excitation from gearing, used to be calculated, until recently, in the MSC Nastran software. However, the calculations performed with this software, could not help us to optimize the stiffness of the housing with respect to the distribution of mode shapes in the speed range of the gearbox. It is not possible to use these calculations results for further calculation of noise emission. For these reasons, we have started co-working with Hexagon, which offers software that includes a comprehensive solution with an overview of all excitation frequencies and resonance frequencies. Only in the case of such an overview, it is possible to optimize the transmission to reduce noise emissions. This overview enables us to control both – the durability calculation and the dynamic properties. Figure 8 shows examples of the actual modal shapes of the gearbox housing and the motor.

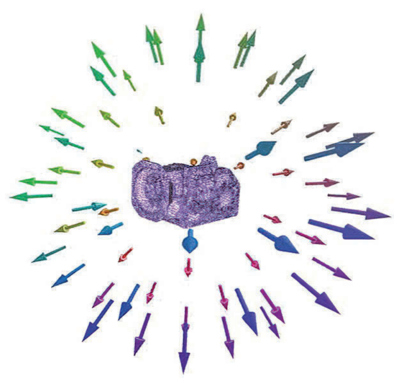
Figure 8: Examples of the mode shapes



Source: own elaboration (2021)

Before starting the calculation of the acoustic emission emitted from the gearbox housing, it is necessary to calculate the TE (Transmission Error) in the entire speed and load spectrum as a basis for the ODS (Operation Deflection Shape) calculation. Based on the complete ODS calculation, it is possible to start the calculation of the sound pressure level of the gearbox at a distance of 1 m from the surface of the gearbox. An example of the acoustic field around the gearbox is shown in Figure 9. The figure clearly shows that the noise emission differs from one side of the gearbox to the other.

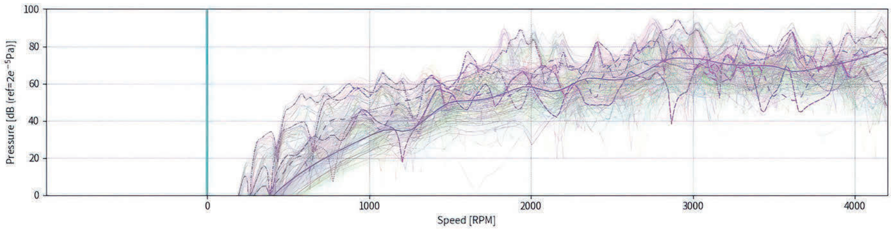
Figure 9: Acoustic field of gearbox (Romax, using embedded technology from Actran)



Source: own elaboration (2021)

At each point where there is an arrow, it is possible to read the result of the sound pressure level as a function of speed (Fig. 10) and the sound pressure spectrogram (Fig. 11). Several resonances amplifications can be seen in figure 10 from the sound pressure for the harmonics of the gear mesh frequency from 0 to the maximum rpm. If these areas exceeded the summarized limit of sound pressure level, the gearbox would need to be re-optimized. In this case, limit has not been exceeded.

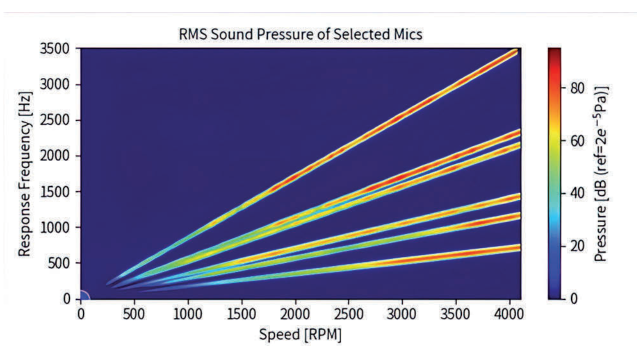
Figure 10: Level of the acoustic pressure for the whole range of rpm



Source: own elaboration (2021)

Figure 11 shows in the spectrogram the course of each harmonic gear mesh frequencies for both gear pairs in the speed range of the transmission at a given load. The approximate situation with tonality for the required speeds can be read from the spectrogram. The key requirement for tonality is that the protrusions of gear mesh frequencies are as small as possible. That applies also for their harmonic and non-harmonic values in FFT and CPB spectra. In this spectrogram, the tooth frequencies of the bevel gears and the second harmonic frequencies of the helical gears are very close, which is unsuitable in terms of tonality. It is better if these waveforms are more apart to fill the empty space without sources of noise. Furthermore, it can be seen from the spectrogram that the resonant regions are distributed over multiple harmonic frequencies of the gears, so that this case is better for tonality.

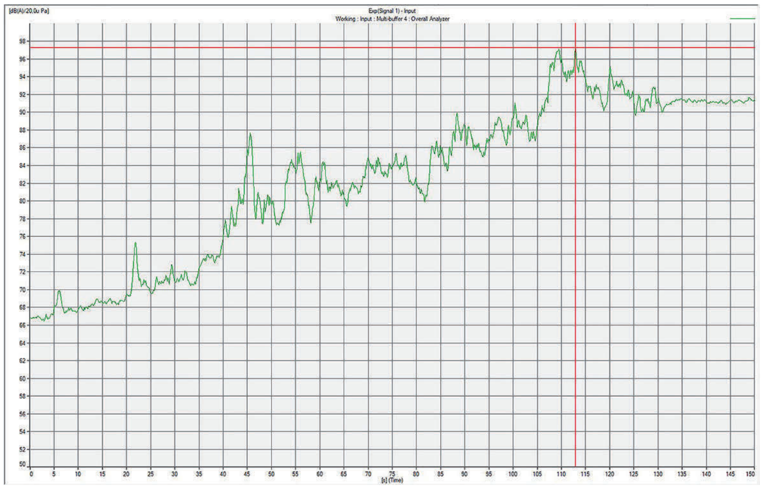
Figure 11: Spectrogram for the excitation from gear mesh



Source: own elaboration (2021)

After the gearbox optimization to reduce the acoustic emission and the actual production of the gearbox prototype, we made verification measurements of the sound pressure level of the gearbox on the test equipment. The measurement was performed using a Pulse device from Brüel & Kjær.

Figure 12: Real measurement of the acoustic pressure for the runup in CW direction



Source: own elaboration (2022)

4. Conclusion

Based on an assessment of the benefits of extending the pre-production phase of the gearbox design through experimental work and optimization using software tools such as Romax, we can say that the new prototype gearbox met noise limits even with a necessary reserve. After a detailed analysis of the results of simulation tools and measurements on the prototype, we obtained very similar results. Any deviations between actual measured data and calculation data may be due to the difference between the actual mounting of the gearbox on the real tram as it was simulated and mounting on the test stand.

Acknowledgements

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Application of additive manufacturing in forming and forging processes

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Abstract

The goals of research and development in the field of Additive Manufacturing (AM) are focused currently on the search for industrial applications and to include these technologies in the common production process. This paper presents all activities in the Additive Manufacturing area in COMTES FHT. The COMTES FHT focuses on topological optimization, structural analysis, thermal analysis and numerical simulation of AM process, additive manufacturing, mechanical testing and metallographic evaluation of deposited samples and components. The function edges and layers on tools for forging and forming made by AM will be presented in this paper.

Keywords: deposition, additive manufacturing, closed die forging, open die forging, tools

JEL Classification: I230, O310, L740

1. Introduction

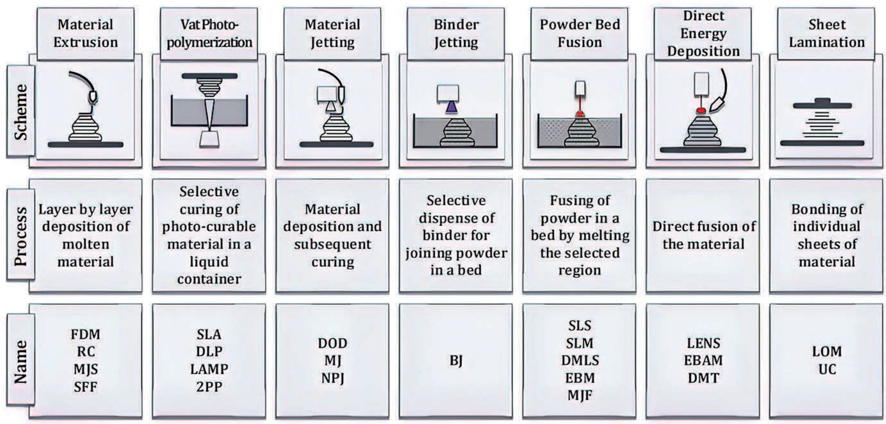
At present, additive manufacturing is increasingly expanding in industrial applications and a relatively large number of institutions are studying this issue. It can be stated that the initial estimates of how this new technology will affect manufacturing capabilities and the general industry have not been confirmed. Based on the growing knowledge of these technologies, it appears that they will take up a very specific position among the standard manufacturing technologies and will complement them in an appropriate way.

In our company, we deal with not only research and development in AM technologies area but the possibilities of applying AM technology in common technological procedures. The benefit of AM technology is mainly in the fact that it allows you to make a part of a general shape, which would be very difficult to produce in the usual way or would be high material consumption.

2. Additive manufacturing

Several technologies are used for additive manufacturing, which is generally divided according to the source of thermal energy and the type of input material. According to this principle, it is possible to identify seven types of AM technology, as shown in Figure 1, which was published in 2017.

Figure 1 Additive manufacturing principles



Source: (Dilberoglu, 2017)

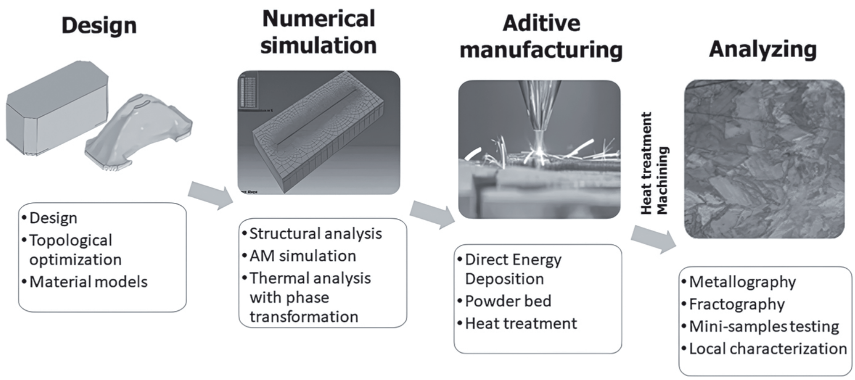
Figure 1 shows the following basic types of AM technology (shown from left):

1) Material Extrusion - laying molten material layer by layer
2) Vat Photopolymerization - selective lighting of light-curable material dissolved in a liquid
3) Material Jetting - laying the material in layers and subsequent curing
4) Binder Jetting - selective dosing of the binder for the connection of powder laid in layers
5) Powder Bed Fusion - melting of powder laid in layers
6) Directed Energy Deposition – direct melting of powder material
7) Sheet Lamination –- glueing of individual sheets of material

COMTES FHT has available various types of AM technologies, Fused Deposition Modeling (FDM), Powder Bed Fusion (PBF) and Directed Energy Deposition (DED) technologies. FDM Technology uses the extrusion of plastic material and our parts are deposited by 3D printer Průša I3 MK3S. Another device called Aurora uses PBF technology is for depositing smaller metal parts and the last technology DED are available on two machines by Korean producer InssTek. There are two machines in our lab, InssTek MX 600 for industrial application and MX-lab for fundamental research.

We are currently proposing to solve the AM process in the whole chain: part design, numerical simulation, additive manufacturing and finally evaluation of properties of additive manufactured parts. In each step there are many substeps, see Figure 2. (Darabi, 2021) (Urbánek, 2022)

Figure 2: AM process step by step

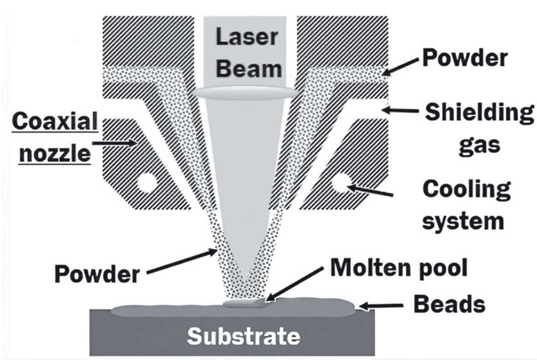


Source: author's photo and elaboration

PBF technology is especially suitable for the production of new small parts from metallic materials. This is mainly due to the fact, that during depositing, a layer of powder is melted by laser in the appropriate places, and after deposition, the part is removed from the supports. The main advantage of this technology is that it can deposit any shape with high quality and accuracy.

DED technology is used more for industrial applications in the field of forming technology. It seems to be more advantageous when the metal powder is transported to the required place and there the powder is melted by the laser. The melting point is protected by the argon atmosphere. This principle allows the creation of functional edges and layers of tools and repairs without limiting the number of deposits.

Figure 3: The principle of DED



Source: (Ahn, 2021)

The principle of DED is shown in Figure 3. This method allows the gradual construction of shapes from different materials, it also allows the local material deposition. This method is suitable both for rapid prototyping and for repairing or depositing more durable materials on functional edges and surfaces.

3. Case studies of DED in hot forming processes

The AM used in the hot forming field is mainly in the ability to combine common materials and tools materials with increased resistance to high temperatures. At present, depositing processes are used for material combination. DED has the advantage of sufficient accuracy and cost savings.

3.1 NIMONIC 80A

Nickel alloy calls NIMONIC 80A is already used in the field of hot forming, especially for worn tool edges. This material has an advantage, especially in higher abrasion resistance at elevated temperatures and higher temperature stability. The chemical composition of the material used is given in Table 1.

Table 1: Chemical composition of the NIMONIC

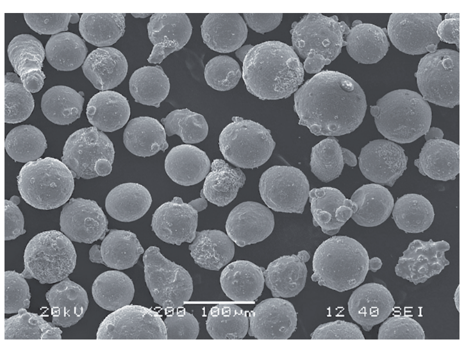
Ni	C	Mn	Cr	Co	Fe
bal.	0.1	1.0	19.5	2.0	3.0

Source: author's measurement data

NIMONIC 80A for AM was prepared by atomization and fine spherical powder with a particle size of 45 – 106 mm was deposited (see Figure 4). The following parameters are checked before deposition:

- powder humidity
- porosity of particles
- regularity of shape
- size and number of satellites
- homogeneous chemical composition
- no oxidation

Figure 4: Powder quality evaluation



Source: author's photo

The tensile tests of deposited Nimonic were performed before the application for production tools. The mechanical properties are shown in Table 2. The tests were performed in three directions (X and Y = directions in the plane of the applied planar surfaces, Z = direction of laying of the layers). Also, ultimate tensile strength was evaluated on the boundary between deposition and tool material, which was chrome-molybdenum–silicon–vanadium steel 1.2343.

Table 2: The mechanical properties

Direction	YS [MPa]	UTS [MPa]	A [%]
X	714±4	945±6	21±1.2
Y	692±12	939±4	23.9±0.4
Z	613±5	809±2	41.1±0.7
boundary	-	793±8	-

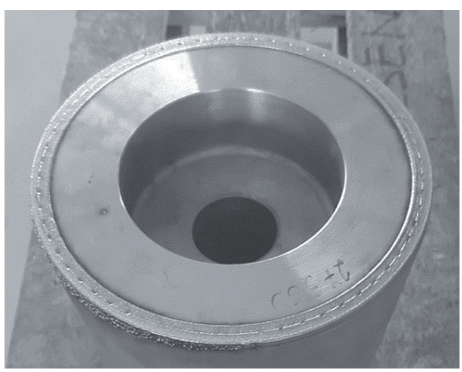
Source: author's measurement data

The measured hardness of the deposited NIMONIC was 260 HV10.

3.2 Trimming punch for piercing

The first application of Nimonic deposition was a trimming punch for piercing forgings (see Figure 5). The material of the punch was C45 and the functional edge was deposited from NIMONIC alloy. The diameter of 250 mm and height of 350 mm were punch dimensions.

Figure 5 Trimming punch with a deposited edge



Source: author's photo

Deposition parameters:

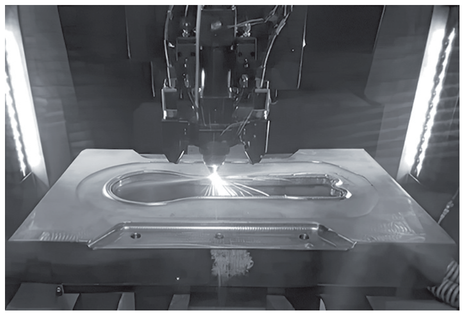
SDM 800 module,

- process time 3 hours,
- laser power 350 – 450 W,
- speed 850 mm/min,
- amount of powder delivered 3 g / min,
- shielding gas argon 5.0.

3.3 Trimming die

The second study case was the functional edge of a trimming die for flash trimming of a connecting rod (see Figure 6). The tool material was S355 steel and Nimonic alloy was used as such deposition material. The tool dimensions were 800x350x50 mm.

Figure 6: The trimming die – deposition process



Source: author's photo

Deposition parameters:

- SDM 1800 module,
- process time 1 hour,
- laser power 900 – 1050 W,
- speed 850 mm/min,
- amount of powder delivered 12 g / min,
- shielding gas argon 5.0.

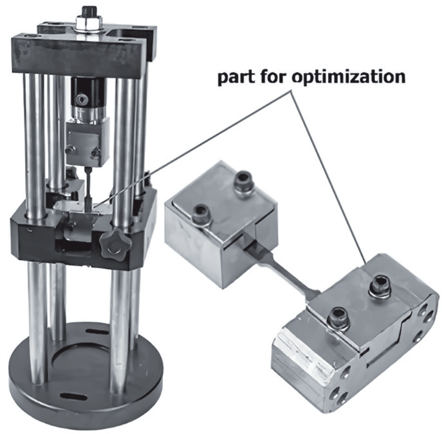
4. Case studies of DED in cold forming processes

The main goal of the DED AM application is to increase the lifetime of the tool, part or component. The materials with high mechanical properties, lower friction properties or lower weight are used for AM applications in the area of cold forming processes.

4.1 Grips for drop weight tower

Grips for drop weight tower is not a typical application in the field of forming technology, but a field of mechanical testing. The reason was a demonstration of the whole chain in AM area in COMTES FHT. That means to show the whole process from the part design, topological optimization using structural analysis to the production itself.

Figure 7: The grip for drop weight tower

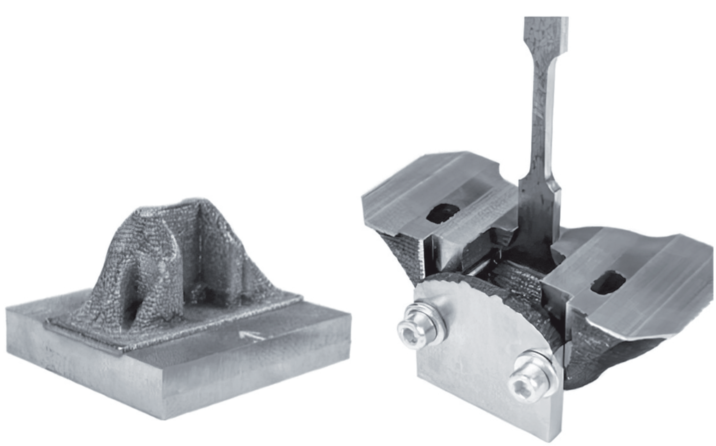


Source: author's photo

The result of accuracy analyses of the dynamic impact test has investigated that the weight of grip (see Figure 7) is too heavy for specimens made by PA, PP or PE. The current weight is 828 grams and that influences the test results.

For these reasons, the testing setup was redesigned using topological optimization, reducing the weight to 127 grams to 15%. By using a material with lower specific gravity, titanium Ti-6Al-4V Grade 5, with the current grip design, the weight would be reduced to 478 grams or 57.7%. Using material with lower density, topological optimization and AM DED technology, the new grip (see Figure 8) has weigh 73.4 grams and which is 8.8% of the original weight.

Figure 8: Optimized grip

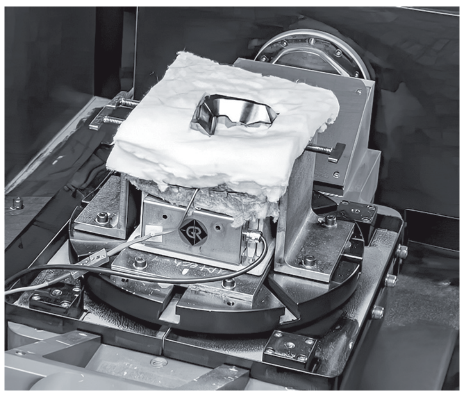


Source: author's photo

4.2 The insert of the cutting tool

The next study case was the insert of a cutting tool for the deep drawing process. The tool steels M2 and T15 were deposited in such a functional layer of the cutting edge. Preheating of the insert was used due to the high content of carbon and alloying elements. It was necessary to preheat the base material to a temperature of 400 °C, in order to quality deposition of the material and the formation of the cutting edge were ensured. A pre-heated part was put on the heating plate and homogenous temperature distribution was provided by Sibral insulating material. The clamped part with isolation is shown in Figure 9.

Figure 9: Insert under heating plate



Source: author's photo

The insert with a functional edge after machining is shown in Figure 10. The boundary between basic material and deposition is seen also after milling.

Figure 10: The insert after milling

Source: author's photo

Deposition parameters:

SDM 1600 module,

- process time 1 hour,
- laser power 850 – 1000 W,
- speed 850 mm/min,
- amount of powder delivered 6.5 g / min,
- preheating temperature 400°C
- shielding gas argon 5.0.

5. Conclusion

AM technology is very progressive and is gaining an irreplaceable place among technological processes. The usability of AM in industrial practice is highly dependent on the chosen principle of deposition and application itself.

Based on the result of this paper, Additive Manufacturing using Directed Energy Deposition proves to be the most beneficial for application in the field of hot forming technology. The presented cutting edge applications were carefully selected mainly from the point of view of comparison with standard technologies, which were made by welding of layers. Evaluation of AM usability takes into account not only the advantages of this technology but also its disadvantages. The biggest disadvantage, which is also the most visible, is mainly the time aspect when the printing times are in the order of hours.

The main advantage of AM DED is mainly in higher accuracy in comparison to welding. Moreover, AM reduces the machining time of functional surfaces after deposition, which is problematic for hard materials, and also reduces the amount of material required. Higher accuracy also brings a lower probability of defects in the layer and cohesion between the base and deposited material.

Initial comparisons show 3 times longer tool life of the cutting tool with a deposited edge made of NIMONIC in comparison to CAPILLA 66 welds. The test has not been completed yet. The tool for cold cutting sheet metal with a deposited edge made of steel M2 has already 50000 pieces and the test also has not been completed yet.

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Application of the AHP Decision Making Method in Warehouse Management in the Metallurgical Company

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Abstract

The aim of this paper is to present the possibilities to implement the model of system based on the AHP method for optimization of multicriteria decision-making process in warehouse management in metallurgical company. First part of the paper will contain the literature review about AHP method in general and about use cases of application of AHP in manufacturing industry companies. In the second part of the paper the case study of application of the AHP based model for support of decision-making in process of storing finished products in the expedition warehouse of medium-fine rolling mill in selected metallurgical company. First the current state of production and logistics processes was analysed. Then the model for dynamic management of the organization of the expedition warehouse of a metallurgical company was constructed. In the last part of this paper the application of the proposed model on two selected warehouse events in defined warehouse conditions will be presented. The selected problem will be solved in specialized SW for AHP. The results of the model application will be evaluated. Finally the conclusions and recommendations for application of AHP method in industrial warehouse management will be deduced.

Keywords: multicriteria decision making, warehouse management, AHP, metallurgy, inhouse logistics

JEL Classification: L00, L61, L23

1. Introduction

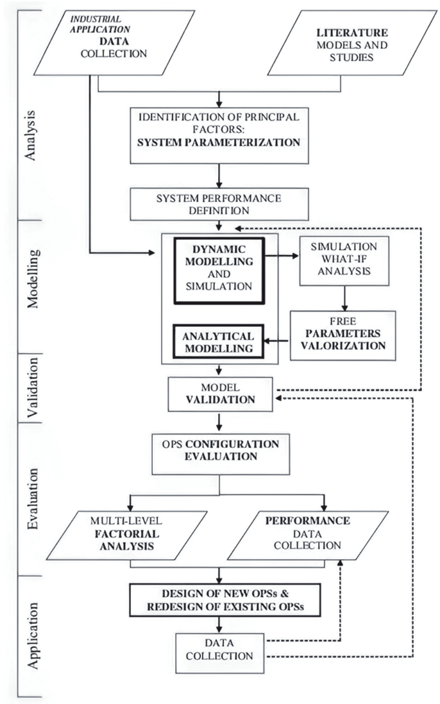
Many managerial decision-making problems are usually determined by multiple, partially conflicting, goals. Multiple criteria decision-making (MCDM) tools help user achieve conclusive decisions with the individual preferences as to the selected criteria and evaluated alternatives (Zavadskas and Turskis, 2011). MCDM methods, as the appropriate techniques used in complex decision situations, vary according to the form of the available information about decision-making problem. In addition, MCDM tools deal with different needs of managers and decision makers. Decision settings requires experiences and preferences of multiple decision makers, whose participation may significantly improve the outcome of strategic decision environment. Analytic hierarchy process (AHP) was proposed as a decision-making technique to evaluate multiple criteria alternatives among one or more decision-makers, using hierarchical schedule of decision levels (Saaty 1986). Since its inception, the method has made significant progress, and, in particular, a number of business applications have been published. The method is based on a pairwise comparison of criteria and alternatives on several levels. Unlike most ordinary MCDM methods based on a pairwise comparison strategy, the cardinal advantage of the method consists in the expression whether a decision maker has a weak, strict, strong, or very strong preference for one item of the pair. Gajpal, Gannesh and Rajendran (1994) proposed AHP to evaluate alternatives in manufacturing organisations. Yurdakul and İÇ (2005) published a model for getting the overall performance score of the manufacturing company's operational activities. Singh and Singh (2011) developed a three-level AHP-based method to solve multi-objective facility layout in manufacturing system. The advantages of hierarchical modelling in AHP discussed Ishizaka and Labib (2011). Larrodé et al. (2012) suggested an AHP-based methodological approach to analyse the process of technological differentiation in the automotive industry. Muerza et al. (2014). applied the AHP method to a general technological diversification process in the Spanish automotive industry. There is a logarithmic relationship between the two methods that we will extensively employ in the elicitation of preference information. Since it allows the inclusion of subjective factors, it is considered as an advancement compared to other decision-making methods. AHP has been applied extensively, especially to large-scale problems involving multiple criteria, and where the evaluation of alternatives is mostly subjective. This paper describes how applications of stand-alone and integrated AHPs evolved and discusses the development over time of the main contributions in this field, to provide an original historical perspective on AHP. The aim is to identify seminal studies that have played a major role in the development of AHP and, also, to identify areas of its adoption. The study uses quantitative methods to identify the set of papers that have contributed most to AHP development and to discover recent major AHP activities. The literature contains several important surveys (Chai, Liu, and Ngai 2013; Ho 2008; Ishizaka and Labib 2011; Sipahi and Timor 2010), but the present paper is the first to investigate AHP adopting a longitudinal perspective on both its methodological development and applications, based on quantitative analysis. Our aim is to provide an in-depth understanding of the scientific communities working on specific applications of AHP and to analyse the on-going debate on the different AHP approaches proposed over recent decades. This study method can be described as quantitative, qualitative and citations network based. The need for a quantitative analysis of this work emerged as the result of the growing number of publications that no longer allow comprehensive qualitative analysis.

The main goal of this paper is to present the implementation of the model of system based on the AHP method for optimization of multicriteria decision-making process in warehouse management in metallurgical company. Implementation of proposed model will be presented via the case study of application of the model for support of decision-making in process of storing finished products on two selected warehouse events in defined warehouse conditions will be presented in the expedition warehouse of medium-fine rolling mill in selected metallurgical company.

1.1 Literature review for publications in the field of organization and organization of the warehouse

During a research of scientific publications in the field of layout, organization and management of the warehouse, it was found that most authors deal with the organization of the warehouse, especially in terms of efficiency of batching and picking orders. This fact is confirmed by the authors Cergibozan a Tasan (2019) in a study focused on current developments and trends in this area. Most authors direct their efforts to create such a warehouse arrangement, which will lead to more efficient order picking when shipping goods. (Li, 2011). In a few cases, however, the authors set out on the way of dynamic warehouse organization optimization systems, which constantly recalculate the optimal warehouse organization scheme based on current data on warehouse status, orders, etc. Cergibozan and Tasan (2019) consider a dynamic and multi-criteria approach to solving the tasks of warehouse management to be necessary in the future. Manzini, Gamberi and Persona (2007) present an integrated approach to supporting the decision-making process in optimizing the OPS (order picking system). Their study aims to identify the impact of different storage and picking approaches and strategies on the system's response to customer orders. To do this, they analysed hundreds of industrial systems and performed thousands of simulations of various scenarios. Based on these analyses and simulations, they proposed a multiparametric dynamic and analytical model. When verifying and evaluating the proposed models, they identified the most important factors affecting system performance and their effects were measured by more factorial analysis. Figure 1 shows a process diagram summarizing the main steps of the proposed integrated approach. The procedure described and illustrated inspired the creation of the model presented in this article.

Figure 1: System design with a multi-level integrated approach



Source: Manzini, Gamberi a Persona 2007

1.2 Literature review in the field of multi-criteria warehouse management decision-making

In their study, Pferschy and Schauer (2018) address the issue of order batching and routing when picking up these batches at the distribution center of e-commerce company. They consider the structure of the warehouse and the storage strategy to minimize the length of routes when picking. They developed a heuristic algorithm to solve this problem. The output of the study is a proposal of a new method of ordering batches and subsequent tracing of picking these batches, which they tested using computer simulation of four scenarios considering the expedition of 785 to 1562 orders consisting of 1,559 to 3,168 items. They state that the method proposed by them will lead to an average reduction of the picking route by 34.7%. Authors Derhami, Smith and Gue (2020) discuss the design of an optimal pallet warehouse layout based on simulations. They deal with the determination of the number, width and length of alleys and the number of intersections. Their goal was to design a layout of warehouse aisles that would ensure a compromise between handling costs and the efficiency of storage space. To achieve this compromise, they developed a simulation using an optimization algorithm. They applied this algorithm in the food industry company and found that it saves 10% of logistics costs associated with the operation of the warehouse. Chan and Chan (2010) published a case study dealing with the issue of selecting a storage location for a stored item in a manually operated multi-level pallet rack warehouse. They consider the distance and time needed to remove the order as a key indicator of the efficiency of the chosen storage method. They state that when choosing a suitable warehouse management strategy and material storage method, it is necessary to consider the method of order picking, size and arrangement of the warehouse, the method of material handling, properties of stored items, customer behaviour, inventory turnover and space requirements. Vidal Vieira et al (2017) present a methodology for the design and planning of logistics activities in distribution centres (DC). The aim of this research is to design a framework for designing DC operations based on a joint study of three elements: distribution strategy, internal activities and characteristics of distribution operations. One of the outcomes of their work was the AHP decision tree for the design of logistics activities in the DC, which captures all the decisive criteria and which takes into account logistics trade-offs. The proposed AHP model of the decision problem has a very complex structure. Global criteria are receipt, shipping, picking and purchasing. In his work, Dmytrów (2020) dealt with the selection of a suitable combination of storage method and method of order picking. He used multi-criteria decision-making methods to select suitable methods. He defined the storage locations by three criteria: the distance from the delivery point, the level of satisfaction of the order and the number of products being picked near the location. He also verified the results of his calculations with computer simulations. During the simulations, he used 37 combinations of criteria weights and 18 different formulas to normalize the weights. He tested each combination on 1,000 generated orders. The result of his work was the finding that the best results were achieved when applying the diagonal arrangement of the warehouse using the ABC method, in combination with reverse tracing during picking.

2. Problem Formulation and Methodology

The aim of this paper is to present the case study of application of the AHP based model for support of decision-making in process of storing finished products in the expedition warehouse of medium-fine rolling mill in selected metallurgical company. After the current state of production and logistics processes was analysed the model for dynamic management of the organization of the expedition warehouse of a metallurgical company was constructed. This model is presented below. In the next chapter of this paper the application of the proposed model on two selected warehouse events in defined warehouse conditions will be presented.

2.1 Model and Data

The process map in Figure 2 shows a model of the proposed decision support system for storing bundles of finished products in the expedition warehouse of a medium-section rolling mill. The following is a text description of the individual steps within the system (Malčic, 2019):

1. Stored bundle

The input impulse to the decision-making process is information about the products being rolled or about the planned rolling campaign, for which suitable storage sites must be selected. This information contains all the necessary characteristics of the newly created bundles and is exported from the SAP system.

2. Expedition warehouse status

Simultaneously with the information about the stored bundle, data on the current situation in the warehouse in terms of available storage, handling and personnel capacities enter the system. Another considered factor is the planned expeditions. Information about the current situation in the warehouse is exported from the warehouse information system WAS.

3. Aspiration level filter

Once all the factors influencing the decision-making process have been processed and evaluated, the system determines the set of allowable storage locations through a series of filters set for the aspiration level.

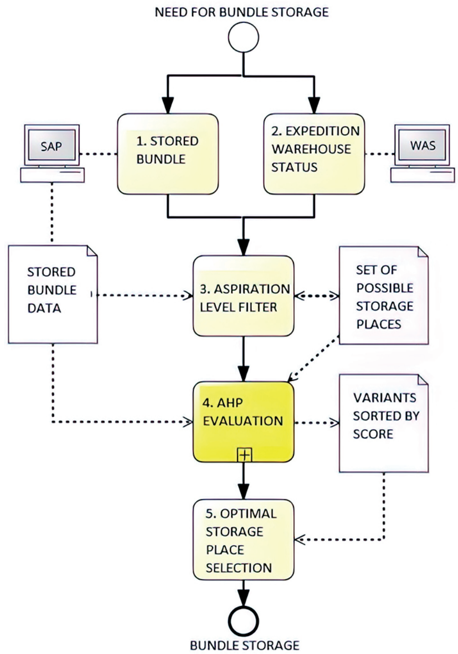
4. AHP evaluation

The set of potential storage places is evaluated using the created AHP model. The evaluated places are sorted according to the achieved evaluation and the system recommends the best rated storage place as optimal for storing the considered volume. The AHP method was selected for solution of the evaluation of allowable storage locations due to multi-criteria nature of the problem. Conflicting priorities of production and logistics department leads to need of assessment of different weight to each characteristic of storage locations.

5. Optimal storage space selection

The last step is to select the optimal storage location for the volume. The proposed system is intended only for decision support. It is not a independent control system. The output of the system is the recommendation of the optimal place and the arrangement of all suitable places. The final decision is up to the responsible employee, who has the option not to accept the recommendation and decide otherwise.

Figure 2: Model of a decision support system for storing bundles of finished products



Source: Malčic,2019

3. Problem Solution

3.1 Application of the proposed model to selected warehouse events in defined warehouse conditions

The proposed model is applied to selected warehouse events in defined warehouse conditions. Cases of storing two different bundles in different storage conditions are presented. For the needs of demonstrating the method of application of the proposed model, the solved problem is simplified. The application of the proposed decision model is implemented in SW SuperDecisons. This SW is used for the construction and synthesis of the AHP model of the decision problem. The selected warehouse events presented below are based on the situation in the expedition warehouse of a medium-section mill in a selected metallurgical company. The examples include a simplified warehouse model, which is complex enough to demonstrate all the functionalities of the proposed system. The examples represent one-time decisions in a static deterministic model.

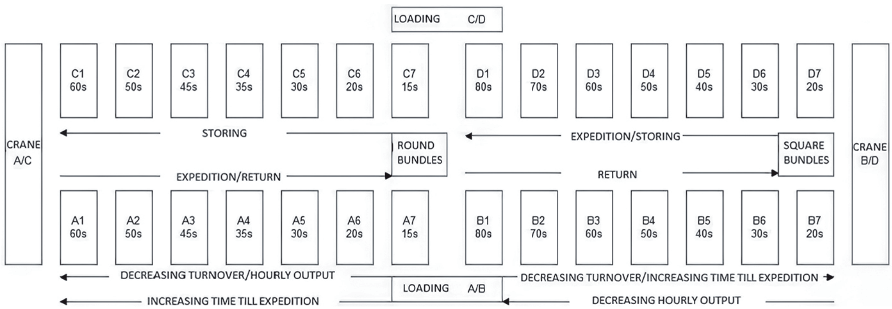
Figure 3 schematically shows a simplified model of defined storage conditions.

Characteristics of the model of defined storage conditions:

- A, C – storage places for round bundles, B, D – storage places for square bundles,
- storage places have allocated times for the arrival of the crane from the place of origin of the bundle in seconds,

- for places A and C, these times also apply to the expedition,
- for places B and D, the times for expedition are the inverse values of the storage times,
- the inscription “round bundles”, “square bundles” represents the place of origin of the bundles

Figure 3: Model of defined warehouse conditions



3.2 Warehouse event 1 – Reinforcing steel ribbed JB31

The first selected stock event is the storage of bundles of reinforcing steel (assortment group JB31). This assortment group was chosen because the analysis of the assortment of stored products showed that it has the highest share in annual production and also the second highest hourly output among round bundles. For these reasons, it is clear that the management of reinforcing ladder steel storage is key to the efficiency of warehousing and expedition processes in the warehouse. More detailed characteristics of stored volumes in the selected warehouse case are given below.

Volume characteristics:

- Assortment group: JB31 reinforcing steel.
- Rod diameter: 16-20 mm.
- Share of annual production: 20.71%.

Current situation in the warehouse:

- Staff capacity: 100%.
- Handling capacity: 100%.
- Delivery bundle location: A6.
- Material bundle location: A7.

Table 1 contains the procedure for filtering storage sites to obtain a set of allowable storage sites that form the aspiration level for the AHP assessment. Storage places A6 and A7 passed the set of filtration criteria of the aspiration level of the AHP model. These two places form a set of admissible solutions and will be further evaluated in the AHP model.

Table 1: Warehouse event 1: stored bundle specifics and warehouse status

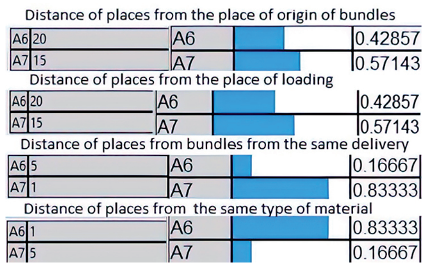
Filter criteria of storage place	Warehouse event 1	
	Bundle	Storage places
Bundle type/Storage zone	Round	A1-7,C1-7
Bundle dimension/ storage place dimension	6m	A2-7,C2-7
Bundle hour output/Distance from bundling	129t/h	A6-7,C6-7
Campaign volume/Storage place capacity	100t(40x2,5t/bundle)	A6-7
Bundle storage time/Warehousing capacity	Friday 20:00 (100%)	A6-7
Expedition date/Storage place attractivity	3 weeks (EXP zone 1/2)	A6-7
Group turnover / Storage space turnover	Medium (TO zone 1/2)	A6-7

Figure 4 shows the structure of the AHP decision problem model for a selected warehouse event by a set of allowable variants. Output of the AHP model is suggested optimal storage place and list of all potential storage places sorted by their score. Crane movements stands for the AHP decision criteria, which are represented by the distance of evaluated storage place from points of interest. Those are PRODUCTION-place of origin of stored bundle, LOADING-loading place for given storage place, DELIVERY-storage places of bundles from the same delivery and MATERIAL-storage places of bundles of the same type of material. Section ALTERNATIVES contains the set of potential solutions.

Figure 4: Structure of the AHP model for Warehouse event 1 in SuperDecisions SW

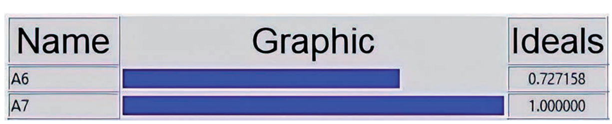
Figure 5 shows the distances of the considered storage places from the points of interest. In the left part of the figure, the respective storage places are assigned a distance in seconds, which represents the travel time of the crane. In the right part of the table is the calculated relative weight of the consequence of the variant with respect to the decision goal. The distances from the place of origin of the bundles and from the loading place are the same, because the loading place for storage places lies close to the bundling line for round bundles. The distance from the storage place of bundles from the same delivery is 5 seconds for the A6 location, because these bundles are stored in the neighbouring and at the same time competitive location A7. This distance was set as 1 for location A7, because the SW does not allow work with zero values. In the case of distance from the same type of material, the situation is the opposite, because bundles of the same material lie at location A6.

Figure 5: Distances of selected storage places from points of interest



All the above distances were synthesized with the specified criteria weights and the result is shown in Figure 6. The final recommendation of the model is to store the considered volumes in storage location A7, which was determined by the model to be about 28% more suitable than location A6. This result is based on the fact that in the first two criteria the storage places are equal and in the criteria delivery and material the situation is exactly the opposite, while for the more important criterion the delivery achieves better values instead of A7. The employee responsible for selecting the optimal storage place will thus receive a recommendations based on calculations based on relevant and current data. In addition, if the reasons that the model does not consider this place would not be appropriate, he will also receive a recommendation for the second best place.

Figure 6: Result of the synthesis of the AHP model for Warehouse event 1



3.3 Warehouse event 2 - – Equilateral angles JV01

The second selected warehouse event shows the application of the proposed system to a different assortment group and bundle characteristics under different storage conditions. This demonstrates the variability and dynamic character of the proposed solution. The second selected warehouse event is the storage of bundles of isosceles angles (assortment group JV01). The specifications of the selected stock event and the defined stock conditions are listed below.

Volume characteristics:

- Assortment group: JV01 isosceles angles.
- Rod diameter: 40x40 mm.
- Share of annual production: 1,82 %.

Current situation in the warehouse:

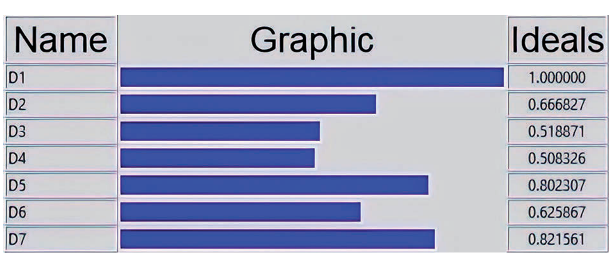
- Staff capacity: 100%.
- Handling capacity: 100%.
- Delivery bundle location: C5.
- Material bundle location: D5.

Table 2: Warehouse event 2: stored bundle specifics and warehouse status

Filter criteria of storage place	**Warehouse event 2**	
	Bundle	Storage places
Bundle type/Storage zone	Square	B1-7,D1-7
Bundle dimension/ storage place dimension	6m	B5-7,D1-7
Bundle hour output/Distance from bundling	89t/h	B5-7,D1-7
Campaign volume/Storage place capacity	50t(20x2,5t/bundle)	D1-D7
Bundle storage time/Warehousing capacity	Wednesday20:00 (100%)	D1-D7
Expedition date/Storage place attractivity	Unknow (EXP zone 1/2/3)	D1-D7
Group turnover / Storage space turnover	Low (TO zone 1/2/3)	D1-D7

There is a clear difference from the previous example, where the result of filtering is a set of allowable storage locations containing only two locations. In this example, a set of permissible locations consisting of 7 storage locations is determined on the basis of the characteristics of the stored volumes and defined storage conditions. This causes a conflict of distance criteria and the selection of the optimal location is thus a more complex problem in the case of selection from a larger number of variants. The assembled model is synthesized and the resulting recommendation of the model is to store the bundles of interest in the storage location D1, which is marked as optimal.

Figure 7: Result of the synthesis of the AHP model for Warehouse event 2



4. Conclusion

The application of the proposed system model to two completely different warehouse events in different defined warehouse conditions demonstrates the variability of the model. However, it also points to a number of problematic shortcomings and problematic factors that need to be optimized before the successful implementation of the system in practice. Apart from the fact that each individual iteration of the decision-making process has a different form and composition of elements, the priorities and parameters of the evaluation criteria will also change, both at the filtering level and at the level of application of the AHP method. It is assumed that the quality of the outputs from the model increases exponentially with each iteration of the decision-making process. This is due to the already mentioned constant development and improvement of the model by users. Furthermore, also due to the gradual reorganization of the warehouse, when with the growing share of volumes stored with the support of the decision-making system, the quality of its decision and the ability to optimize will also increase. Another prerequisite is a reduction in the average level of stored stocks due to more efficient shipping processes, which will allow more freedom in choosing the optimal storage location.

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Analysis of the Driving Assistant Systems and their Impact on Human Behavior and Mind – Philosophy and Methodology of the Planned Research

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Abstract

The paper explains research philosophy and methodology for the project "Synchronising Development of the Assistant Systems with the Capacities of a Human Mind". There exist two basic paradigms of a conceptualization of the relationships between human beings and technologies. Within a prosthetic paradigm technology is perceived and understood as a tool which increases and enlarges human abilities skills and range of action. Within aesthetic paradigm technology is perceived as an integral component of the human beings and their world. In our view it is necessary to refer to both of these paradigms in our research. In respect to this assumption following research questions have been proposed: (1) What is an optimum amount of the assistant systems for the drivers? (2) Which technologies and assistant systems actually help drivers, and which are useless and/or even harmful for them? (3) How do drivers adapt to driving assistant systems? Planned empirical research on the samples of both professional and "ordinary" drivers will try to answer all of these research questions.

Keywords: aesthetic paradigm, cyberpsychology, drivers, driving assistant systems, pilot study, prosthetic paradigm

JEL Classification: L62, L94, O18, R41

1. Introduction

The paper presents research philosophy and methodology for the partial research task "Synchronising Development of the Assistant Systems with the Capacities of a Human Mind" This research task represents one of ten tasks of a complex project entitled "Modern Technologies in area of Committing, Investigating, Proving and Preventing Criminality for the Purposes of Public Order and Safety in Road Transportation". The project is solved by consortium of eight partners – Slovak Republic Ministry of Internal Affairs, Slovak Republic Police Constabulary, Police Constabulary SR Academy, Czech Republic Police, The University of Finance and Administration Prague, Iris Ident Slovakia, Czech Republic Probation and Mediation Service, ŠKODA Auto University.

The project started in 2019. Covid pandemic has interrupted the works till the end of 2021, however. In other words, solution of the project tasks restarted again in January 2022.

Research task "Synchronising Development of the Assistant Systems with the Capacities of a Human Mind" follows several interrelated partial objectives: (1) Detailed analysis of the driving assistant systems used or planned for the use in motor vehicles; (2) Identification of the trends in the area of development and implementation of driving assistant systems; (3) Analysis of the impact of these systems on human mind and behaviour. These goals were formulated in respect to two research expectations rooted in both everyday life experience and general psychological knowledge: (a) Ordinary driver is unable to effectively use all of the existing driving assistant systems; (b) Frequent use of the driving assistant systems leads to atrophy and deterioration of the driver's skills and habits.

The first part of the paper describes philosophy and methodology of the planned research. It explains the nature of prosthetic and aesthetic paradigms/approaches to technology – human interaction and relationships. It presents results of the recent studies focused an interaction between drivers and different driving assistant systems and argues for a need to integrate both of these paradigms in our research. Drivers of the cars equipped with the new digital technologies can be understood also as a specific kind of cyborgs. Therefore, cyberpsychology was identified as another useful philosophical reference for the planned research.

Explanation of the philosophy is followed by description of the research methodology. This paper is focused on the third partial objective of our project - Analysis of the impact of the driving assistant systems on human (drivers') mind and behaviour. As the main data collection technique was chosen a questionnaire. This paper describes content and structure of the first version of the questionnaire (including its links to our research questions) constructed for the purposes of a pilot study. After a pilot study a definite version of the questionnaire will be constructed, and data will be collected on the samples of the professional as well as ordinary drivers. Questionnaire survey results will be validated by semi-structured interviews.

The second part of the paper describes the most interesting and important results of a pilot study and proposes next steps for our research.

Conclusion relates results of a pilot study to other studies focused on analysis of driving assistant systems and summarizes key challenges and tasks for future research, development and use of assistant systems.

2. Research Philosophy and Methodology

Ongoing continual implementation of the driving assistant systems into vehicles represents a specific case of human – technology interaction. Therefore, our research should refer to basic paradigms of a conceptualization an interaction between human beings and technologies. There exist two basic approaches to a solution of this question – prosthetic and aesthetic paradigms (Corbett, 2009).

Within a prosthetic paradigm technology is viewed as an extension of human capabilities, skills, and agency. For example, microscope enables people to see objects which are too small for unaided human eye to register. Prosthetic approach to driving assistant systems consequently leads to their understanding as the "tools" which are improving drivers' performance in different respects – i.e., safety, orientation in traffic, parking, using the phone.

Within an aesthetic paradigm technology is seen as integral part of human beings. Technologies are changing the ways people make sense and perceive the world, so human world is also changing – "once microscopic things became visible to scientists, the very way these things are represented and theorized by scientists also tends to change" (Corbett, 2009, p. 11). In this perception people interiorize technologized ways of perceiving themselves and their world. Aesthetic approach to understanding technology often refers to concept of cyborg – technologies cannot be separated from the mind and body. Aesthetic understanding of the driving assistant systems views these technologies as integral components of driver's mind and body. Through the use of these systems drivers are developing new ways of both using and understanding/perceiving their "own" car as well as other "driving world" relevant realities.

Reference to cyborg resonates with the new psychological discipline called cyber-psychology. Cyberpsychology is defined by its founder Suler (2016, p. 22) as the study of cyber-psyche, the computer mind "out there" created by the fusion of humans and machines. Suler (2016) understands cyberspace as a psychological space which can be described by the means of eight fundamental dimensions: (1) The identity dimension: Who am I? (2) The social dimension: Who are we? (3) The interactive dimension: How do I do this? (4) The text dimension: What's the word? (5) The sensory dimension: How am I aware? (6) The temporal dimension: What time is it? (7) The reality dimension: Is this for real? (8) The physical dimension: Is this tangible?

In respect to our research focus on the use of driving assistant systems in vehicles in particular three fundamental dimensions of cyberspace should be considered (Suler, 2016):

- The sensory dimension and its concerns with the questions like: How do we rely on different stimuli from cyberspace? What kind of stimulation we do prefer?
- The reality dimension and its concern with the questions like: How do we differentiate between reality and fantasy in cyberspace? How do we react to real versus imaginary situations?
- The physical dimension and its concern with the questions like: How does the use of digital tools and technologies affects our body? How do we use devices to interpret and react on our environment?

In our view it is necessary to combine both paradigms (including aesthetic paradigm's resonance with cyberpsychology) in our research. We should try to understand both how driving assistant systems influence skills, capabilities, and reactions of the drivers (prosthetic approach) and how are they integrated into the ways drivers understand and "operate" with different "driving world" relevant realities that surround them – cars, traffic, drivers, and other participants in everyday traffic etc. – (aesthetic approach).

Recent studies of the human perception and use of (digital) technologies and/or driving assistant systems led to several interesting findings.

Vejačka (2016) studied which factors have positive influence on peoples' adoption of new digital tools and technologies (eGovernment in particular). He came to conclusion that significant influence on adoption of new technologies have perceived usefulness, perceived security, amount of information and perceived quality.

Study conducted by Mlekus et al. (2020) identified quality of output, novelty, dependability, and perspicuity as the significant general predictors of technology acceptance. Authors of the study came to conclusion that future users' opinions should be involved in the technology design process. Analogical "bottom-up" approach recommended earlier also Crabu and Magaudda (2018).

Psychological study conducted by Ho-Chang et. al. (2020) suggests that an individual's cognitive style influences perception of the usefulness and ease of the new (digital) technologies. People with introversion, thinking and judging cognitive styles tend to perceive higher ease of use of new technologies than those with extroversion, feeling and perceiving cognitive styles (this typology was proposed by C.G. Jung originally).

There exist series of studies focused on accommodation of the driving assistant systems to human bodies/abilities.

Study focused on vibrations warnings to drivers via Bluetooth earphones or smart wristbands demonstrated that vibrations on the upper jaw has the shortest simple reaction time and choice reaction time (Zheng et al, 2021). Vibration warnings on driver's upper jaw is more effective than those on wrist and shin.

Another interesting study assessed the effects of different warning messages on driver's ability to avoid a potential safety hazard (Wu and Boyle, 2020). Authors came to conclusion that it is useful to combine speech-based cues (i.e., Brake now, Danger, Vehicle on your left) with non-speech-based cues (beep). This finding indicates the need to attract driver's attention via a combined stimulation of the different receptors.

Bernhard and Hecht (2020) conducted study investigating the effects of different positions of side-mounted rear-view cameras on distance estimation of drivers. On one hand they found out that lower camera position led to distance overestimation and higher position to underestimation. However, the effect of camera position disappeared when the vehicle's back was visible. This indicates that information mediated by camera (and possibly by other assistant systems) should be integrated with unmediated direct perception of the "real" world objects (physical points of reference).

Very interesting trend in a design of the interactions between assistant systems and drivers represents focus on gestures. Graichen et. al. (2019) found out that gesture-based interaction with the systems and tools used in cars helps to reduce visual drivers' distraction which has a highly negative impact on the driver.

Different series of studies is focused on adaptation of drivers to different assistant systems. As very important factors in this respect there were identified understanding and trusting these systems. Tenhunfeld et al (2019) found out that using partially automated parking with little knowledge of its working can lead to mistakes and high degree of initial distrust. Authors recommend short tutorials and brief explanations of the working of these systems.

Lee et. al. (2019) found out that level of trust of automated vehicles depends strongly on a similarity between driver's and vehicle's driving style. This indicate that drivers feel a need to perceive automated cars and possibly other assistant systems as safe and predictable.

Evidence for a need to make driving assistant systems understandable to drivers brought study by Muslim and Itoh (2020). These authors illustrate that taking into account human skills and abilities while designing driver support systems alone is not sufficient. To maximize safety and system usability it is also important to ensure appropriate driver's understanding and acceptance of the system.

Study by Miller and Boyle (2018) indicate that the use of assistant systems (lane keeping system in their case) without understanding and active involvement of the drivers into the process of car control can easily lead to skill atrophy. In other words, besides a training and understanding drivers should not trust assistant systems blindly.

In summary, all the studies mentioned above suggest that: (1) Driving assistant systems should be designed in accordance with the human skills and abilities. (2) There is still a lot of room left for an improvement of interactions between drivers and assistant systems. (3) Information mediated by driving systems should be multichannel. (4) Drivers must understand nature and principles of assistant systems working – they need a training. (5) Driving assistant systems must be trusted by drivers. (6) Drivers must actively participate on a control of semi-automated and fully automated vehicles.

2.1 Methodology of the Research

As it was stated in an introduction research task "Synchronising Development of the Assistant Systems with the Capacities of a Human Mind" follows several interrelated partial objectives: (1) Detailed analysis of the driving assistant systems used or planned for the use in motor vehicles; (2) Identification of the trends in the area of development and implementation of driving assistant systems; (3) Analysis of the impact of these systems on human mind and behaviour. These goals were formulated in respect to two research expectations rooted in both everyday life experience and general psychological knowledge: (a) Ordinary driver is unable to effectively use all existing driving assistant systems; (b) Frequent use of the driving assistant systems leads to atrophy and deterioration of the driver's skills and habits. As we can see above the second expectations was recently confirmed by Miller and Boyle (2018).

Whereas two first objectives can be reached via "desk research", the third goal requires empirical study conducted on drivers. Our team decided to use a questionnaire and interviews for this purpose. In reference to objectives, philosophical background of our project as well as to the results of the studies mentioned above planned empirical research will try to answer three research questions: (1) What is an optimum amount of the assistant systems in vehicles? (2) Which technologies and assistant systems help drivers, and which are useless and/or even harmful for them? (3) How do drivers adapt to driving assistant systems?

Questionnaire will be constructed in two steps. First a pilot version of the questionnaire will be proposed. After a pilot study conducted on samples of both professional and ordinary drivers (see head 3 Results of a Pilot Study) a definite version of the questionnaire will be constructed and used. Questionnaire survey results will be validated by the means of semi-structured interviews with selected drivers.

Pilot version of the questionnaire contained 13 items. First five items were focused on the following topics: if respondent is professional/ordinary driver, respondent's driving experience, explanation of the assistant systems to respondent upon receipt of a (new) vehicle, which assistant systems respondents use regularly and why, respondent's ability to park vehicle into row of cars without assistant system. The rest of the items focused on: respondents' identification of dispensable, indispensable assistant systems and dangerous assistant systems, respondents' use of phone during driving, assessment of impact of assistant systems on road transport safety. On items 6,7 and 8 were respondents offered lists of assistant systems (ŠKODA Storyboard, 2020) with a task to select those, which are dispensable, indispensable, and dangerous.

3. Results of a Pilot Study

Pilot version of the questionnaire was used on a sample of 200 professional drivers (drivers of Integrated Rescue System from Czech Republic – 100 – and Slovak Republic – 100) and of 200 students of combined form of study (Ambis, a.s. and University of Financial Administration). Respondents were addressed via e-mail. There were returned 255 completed questionnaires (50% completed by professional drivers and 50% by students).

Majority of the respondents (60%) reported 10 years and longer experience with (active) driving.

Disappointing results brought reactions on statement: "I was introduced to the assistant systems during upon receipt of the vehicle." 50% of respondents answered "no", 5% "partially" and 45% "yes". Such an approach represents a potential danger and decreases effectiveness of the assistant systems.

As most frequently used assistant system was presented "parking assistant" (75% respondents). 25% respondents presented "cruise". 5% respondents answered they use nothing.

Questionnaire contained also items focused on identification of dispensable, indispensable, and dangerous assistant systems. As dispensable systems there was most frequently identified "lane assistant" (25% respondents). The reasons were – *it doesn't work reliably; it sometimes reads the road wrongly; it tends to fight with you for steering wheel; it tends to prevent me from avoiding an oncoming truck when I need – it is dangerous*. In correspondence with this finding 15% respondents identified "lane assistant" as a dangerous system on separate questionnaire item interested in dangerous systems (10% respondents identified as dangerous touch systems - displays in particular).

As the most indispensable assistant system there was identified "blind spot detector" (20% respondents) and ABS, ESP (10% respondents).

In contradiction to general uncritical expectations only 15% of the respondents believed driving assistant systems are increasing safety of road traffic (25% respondents answered "no" and 60% "don't know"). Among the critical comments on the address of assistant systems there appeared: *they make drivers less alert; they distract attention from driving; people tend to rely on them too much, but systems are still systems which should but don't have to react properly.*

As most of the respondents were reluctant to answer open questions it will be necessary to validate results of definite version of the questionnaire via semi-structured interviews. It seems to be useful to integrate into these interviews also critical incidents technique which can help both to identify the kinds and to understand nature of the dangerous situations following from the use of assistant systems.

4. Conclusion

Results of our pilot study correspond to results of other studies focused on analysis of driving assistant systems and their impact on human behaviour and thought in several respects. It was found out that touch-based manipulation with systems and displays is dangerous. As a promising alternative can be identified development of gesture and voice-based forms of interaction. It seems to be clear that more attention must be paid to drivers' introduction to and training with assistant systems. Also, improvement and/or removal of dangerous systems (i.e., "lane assistant") is important. Last but not least new ways of drivers' active involvement into control of "high-tech" vehicles need to be developed and designed.

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Visual management of security management systems standards for supply chain

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Abstract

The organizations belonging to the supply chain providers, produce products or provide services, can use visual management to improve their effectiveness. Nowadays, the visualization of management systems and relevant standards is presented primarily in the form of tables or static diagrams. Demands for the security of products and services are reflected in the interconnectedness and complexity of standards, which could cause complications during the implementation phase. The main aim of this article points to the support provided by visual management for planning, implementing and maintaining a management system according to ISO 28001"Security management systems for the supply chain – Best practices for implementing supply chain security, assessments and plans – Requirements and guidance". Visual management works with a dynamic cluster model built using the application TouchGraph Navigator. The visualization process began with a detailed examination of the requirements, documented information as well as notes detailed in ISO 28001 and continued with the creation of a central node to which new nodes were subsequently connected, containing the introductory parts of the document, including clauses. The initiation of clauses/sub-clauses for other parts of the standard followed. The dynamic character of the resulting model can be used in the implementation, performance, maintenance, or certification for supply chain providers to improve their supply chain security processes into their operational frameworks.

Keywords: supply chain management, ISO 28001, security, resilience, visualization, cluster, Small World Network.

JEL Classification: Supply Chain, ISO, Network, Services

1. Introduction

The managers in supply chain companies often ask themselves, "What support is provided to address our issues?" The answer is as it often reflects solutions from interpersonal relationships. If you have a problem, try contacting your relative first. Likewise, supply chain management can get help from other managements.

One "relative" is the ISO 28001: 2007 standard Security management systems for the supply chain – Best practices for implementing supply chain security, assessments and plans - Requirements and guidance, which provides an option for organizations' managers to establish and document reasonable levels of security within international supply chains and their components. The standard ISO 28001 will enable such organizations to make better risk-based decisions concerning the security in those international supply chains (ISO 28001, 2007). This strong helper provides support for textual formulations of mandatory requirements and guidance to make it clear how to meet those requirements.

The second eye-catching helper from the "kinship" relationship is visual management, which with the help of pictures, diagrams, clear graphs captures the essence of the solution in a short time. Visual management is a way to visually communicate expectations, performance, standards or warnings in a way that requires little or no prior training to interpret (McIntosh, P., 2017).

For organizations that provide services or produce products, it is appropriate to integrate the management system according to ISO 28001 with other management systems. These are especially the most popular management systems according to the standards that are often required by customers: IATF 16949, ISO 9001, ISO 27001, ISO 45001, ISO 14001, etc. The benefits of integration include unifying common requirements, reducing the amount of documented information, the ability to perform combined audits, and other items that are individual to organizations. However, sometimes limits may arise due to the need for correct integration. It is the competence of human resources, time-consuming and common habits that are very difficult for an organization to change.

The synergistic effect of these three management systems: own management of the organization, the management systems standard and the visual management will be gradually presented in the following text.

1.1 Supply chain management and its basis

Supply chain management (SCM) is based on the idea that nearly every product that comes to market results from the efforts of various organizations that make up a supply chain. Supply chains have existed for ages, most companies have only recently paid attention to them as a value - add to their operations (Fernando, J., 2022).

A supply chain is the network of individuals, companies, resources, activities, and technologies used to make and sell a product or service. A supply chain starts with the delivery of raw materials from a supplier to a manufacturer and ends with the delivery of the finished product or service to the end consumer. How much of this supply chain needs to be managed depends on several factors including the complexity of the product, the number of available suppliers, and the availability of raw materials? Dimensions to consider include the length of the supply chain and the number of suppliers and customers at each level. It would be rare for a firm to participate in only one supply chain. For most manufacturers, the supply chain looks less like a pipeline or chain than an uprooted tree, where the branches and roots are the extensive network of customers and suppliers, (Douglas, M., 2020).

SCM oversees each touchpoint of a company's product or service, from initial creation to the final sale. With so many places along the supply chain that can add value through efficiencies or lose value through increased expenses. SCM can increase revenues, decrease costs, and impact a company's bottom line (Fernando, J., 2022).

Figure 1: The structure of Supply chain Management

Source: https://www.sap.com/sk/insights/what-is-supply-chain-management-scm.html

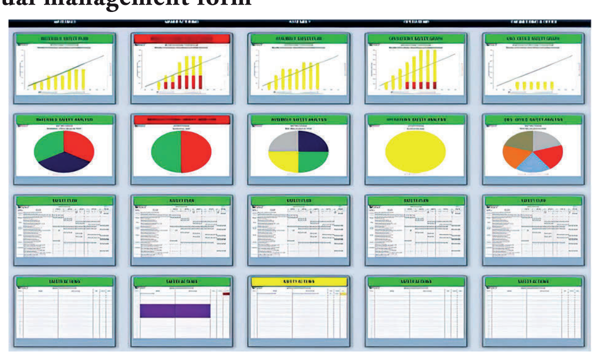
Managing the supply chain, companies can cut excess costs and deliver products to the consumer faster. This is done by keeping tighter control of internal inventories, internal production, distribution, sales, and the inventories of company vendors (Fernando, J., 2022).

Having all these items of chain under control, the managers use various tools to analyse and view individual chain processes. The forms and methods that are the most common are the subject of Visual Management. It is highly used within coordination of production activities as well as the running of internal logistics or applying of supply chain management lean tools.

1.2 The Merit of Visual management

Visual management is a form of communication mostly used to give a snapshot of manufacturing operations. It is a system of information displays, visual controls, labels and signs, colour coding and other markings. The goal of visual management is to translate shop floor processes and production statuses into easy-to-understand visual overviews. With one glance, the whole team can get an understanding of a factory's performance (Tulip, 2020), (see Fig. 2).

Figure 2: Visual management form



Source: (Narad Consulting, 2016)

Visual management of the production process amplifies process transparency. Increasing process transparency of the production process, there is reduced the need of hierarchical communication between subordinate and supervisor. This loosens non-value add bottleneck activities such as asking repetitive questions etc.

Visual tools can be used to habitually maintain correct procedures. By continuously interfacing with visual management, a manufacturer's workforce is influenced into maintaining process standardization throughout the production cycle. The tools of visual management aid improve cognitive and memory function when performing routine tasks. Visual management also facilitates on the job training as information tool pertaining to the production process. This form of training is effective as it engages personnel into practical experience and in the end, it disrupts to a lesser extent the organizational practice (Tulip, 2020).

An effective visual management system seeks to display production status and performance information, communicate standards and work instructions, make problems and abnormalities as apparent as possible and show identity and directions. It can reduce the opportunity for miscommunication, highlights abnormalities and deviations, and provides an immediate insight to what needs to be done next. When problems and deviations are visible and apparent to all, immediate corrective action can be taken to increase the efficiency and effectiveness of the processes. Visual controls are also used to share goals and ideas, report team and Kaizen progress, and indicate safety risks and promote safe behaviour at work (CIToolkit, 2016).

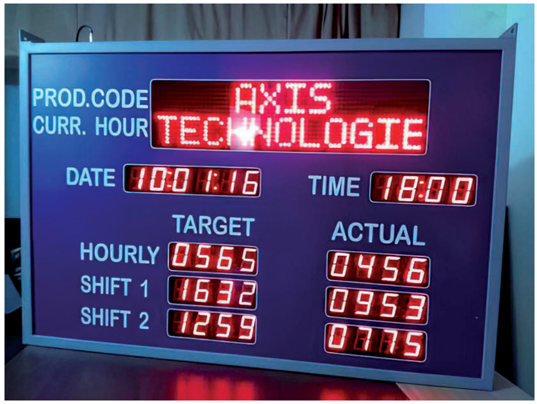
Applying Visual Management the company can greatly improve the efficiency of manufacturing operations. Some of the benefits includes: (CIToolkit, 2016; Tulip, 2020).

- Improved process efficiency.
- Creates stability to the environment, equipment and work performed.
- Reduce errors and mistakes.
- Waste reduction.
- Safer workflows.
- Improves the communication between different shifts.
- Eliminates the need for time consuming meetings.
- Inventory storage that matches production demands.
- Higher team engagement.

Visual management is often applied to **factory layouts**. Assembly lines are organized in a manner to direct production flow from start to finish, with visual indicators placed at important points.

Visual control of this nature employs the **use of labels and markings** throughout the shop floor. They are key sign posts of what actions to take, where to locate a particular item, and what areas are restricted on a shop floor. Visual management also deploys digital information **displays** across the shop floor to highlight e. g. some KPIs (Tact Time, Cycle Time, Planed umber outputs per shift and the real ones, etc.). These forms of display are called Andons and dashboards (see Fig. 3). They broadcast real time analytics detailing shop floor performance.

Figure 3: Andon



Source: https://www.indiamart.com/proddetail/andon-display-board-6484306833.html

Visual control is done by incorporating some **tools and parts.** E. g. Kaizen foams and shadow boards have outlines cut for each specific tool. This provides fast detection if a tool is missing or identifies where to place a tool once it has been used.

Figure 4: Kaizen foam

Source: Timbecon, 2020

Visual management can provide a simple and yet effective solution to enhance information flow in many manufacturing shop floors. Easy access to production information not only maintains the integrity of production quality, but it can also be used to boost efficiency and aid in training process (Tulip, 2020).

If an organization needs to visualize management systems that include formulations of mandatory requirements to better understand the context, it have to look for a suitable tool for that visualization. For example, ISO standards include management systems declared as documents (in paper form).

On the other hand, visualization has the potential to express these documents in a dynamic mode. This is very convenient for a quick and insightful view of the issue. Using the application of the theory of the Small World network, we can also present the binding requirements with their connections, which we would have to laboriously search for in the text. Software support is essential for such processing of management systems according to ISO standards.

1.3 Small World Networks

The small world concept was firstly identified by Milgram, who studied the structure of social networks (Auber, 2003). He took a number of letters addressed to a stockbroker in Boston and distributed them to a random selection of people in Nebraska and Kansas. His instructions were that the letters were to be sent to the stockbroker by passing them from person to person and, in addition, could be sent only to someone whom the current holder knew on a first-name basis. Since it was not likely that the initial recipients of the letters were on a first-name basis with a Boston stockbroker, their best strategy was to pass their letter to someone they presumed was more likely to know the person to whom the letter was ultimately addressed. By requiring each intermediary to report their receipt of the letter, Milgram kept track of the letters and the demographic characteristics of their handlers (Prizmič, J., 2005).

A reasonable number of letters eventually reached their destination, with a median chain length of about six. Milgram concluded that six was therefore the average number of acquaintances separating any two people in the entire world. This situation has been labelled "six degrees of separation", a phrase which has passed into popular folklore. There were certainly enough possible sources of error in Milgram's experiment, from his sample selection to the fact that it was confined to the United States, to suspect that the figure six is probably not a very accurate one. However, the general result that two randomly chosen human beings can be connected by only a short chain of intermediate acquaintances has been subsequently verified and is now widely accepted. This result is referred to as the small-world effect (Prizmič, J., 2005).

The current accepted definition of a small-world network is that it has clustering similar to a regular lattice and path length similar to a random network. However, in practice, networks are typically defined as small-world by comparing clustering and path length to those of a comparable random network (Humphries et al., 2006). Unfortunately, this means that networks with very low clustering can be, and indeed are, defined as small-world (Telesford, Q., 2011).

The discovery of small-world network has revolutionized research in network science.

2. Problem Formulation and Methodology

The company that plans or has implemented management systems in accordance with ISO 28001:2007 takes advantage of this document, which establishes certain documentation requirements that would permit verification and provides guidance in international supply chains to

- develop/implement security processes of supply chain;

- establish/document a minimum level of security within a supply chain or its part;
- assist in meeting the applicable authorized economic operator (AEO) criteria set forth in the World Customs Organization Framework of Standards and conforming national supply chain security programmes.

Stakeholders (managers) will

- define the portion of an international supply chain within which they have established security;
- conduct security assessments on that portion of the supply chain and develop adequate countermeasures;
- develop/implement a supply chain security plan;
- train security personnel in their security related duties (ISO 28001, 2007).

In order for stakeholders to work effectively with ISO 28001, it is necessary to obtain and learn a wealth of information. This is often tedious for them and some requirements are forgotten. A partial solution to this problem is to visualize the document in the form of a small world network model.

2.1 Data collection for management systems model building

The model of management systems standard according to ISO 28001 is built by means of program application TouchGraph Navigator (TouchGraph, 2022), which is used at the Institute of Industrial Engineering and Management, Faculty of Materials Science and Technology in Trnava, the Slovak University of Technology in Bratislava where several models were configured.

The data for creating the model in the TouchGraph Navigator software were prepared in the form of a data file in MS Excel. In Table 1 there are clauses of this standard in context to PDCA (Plan-Do-Check-Act) cycle and the clauses/subclauses are related to their mandatory requirements, mandatory document information and explanatory notes.

Table 1: The clauses of ISO 28001 with their attributes

PDCA cycle	Clauses and Subclauses	Number of requirements	Number of documented information	Number of notes
	0 INTRODUCTION			
	1 SCOPE			
	2 NORMATIVE REFERENCES			1
	3 TERMS & DEFINITIONS			
	3.1 ÷ 3.28			14
	4 FIELD OD APPLICATION			
PLAN	4.1 Statement of application	6		
	4.2 Business partners	3		
PLAN	4.3 Internationally accepted certificates or approvals	0/1		

	4.4 Business partners exempt from security declaration requirement	1		
DO	4.5 Security reviews of business partners	4	1	1
	5 SUPPLY CHAIN SECURITY PROCESS			
PLAN	5.1 General	6	1	
PLAN	5.2 Identification of the scope of the security assessment	5	1	
PLAN	5.3 Conduction of the security assessment			
PLAN	5.3.1 Assessment personnel	9	2	
PLAN	5.3.2 Assessment process	15	3÷4	
DO	5.4 Development of the supply chain security plan	5		
DO	5.5 Execution of the supply chain security plan	1		
	5.6 Documentation and monitoring of the supply chain security process			
CHECK	5.6.1 General	4	1	
ACT	5.6.2 Continual improvement	1		
CHECK	5.7 Actions required after a security incident	5÷7		
DO	5.8 Protection of the security information	3		1
	ANNEX A Supply chain security process			
	A.1 General			
	A.2 Identification of the scope of the security assessment			
	A.3 Conduction of the security assessment			
	A.3.1 General			
	A.3.2 Performance review list			
	A.3.3 Performance review			
	A.3.4 Security threat scenarios			
	A.4 Development of the security plan			
	A.4.1 General			
	A.4.2 Documentation			
	A.4.3 Communication			
	A.5 Execution of the security plan			
	A.6 Documentation and monitoring of the security process			
	A.7 Continual improvement			
	ANNEX B Methodology for security risk assessment and development of			
	countermeasures			
	B.1 General			

B.2 Step one – Consideration of the security threat scenarios	
B.3 Step two – Classification of consequences	
B.4 Step three – Classification of likelihood of security incidents	
B.5 Step four – Security incident scoring	1
B.6 Step five – Development of countermeasures	1
B.7 Step six – Implementation of countermeasures	
B.8 Step seven – Evaluation of countermeasures	
B.9 Step eight – Repetition of the process	
B.10 Continuation of the process	
ANNEX C Guidance for obtaining advice and certification	
C.1 General	
C.2 Demonstrating conformance with ISO 28001 by audit	
C.3 Certification of ISO 28001 by third party certification bodies	
Bibliography	

Source: Authors preparation according to ISO 28001:2007

Table 1 shows that when implementing, maintaining and improving supply chain security management systems according to the standard ISO 28001:2007, it is necessary to satisfy 69 ÷ 71 requirements, to present 9 ÷ 10 documented information. In addition to Annexes A, B and C, the number of explanatory notes is 17 and there are 2 in Annex B. Numeric intervals are given by required or unrequired items of the customer or other interested party This information is also contained in the data file for building the model of the given management systems.

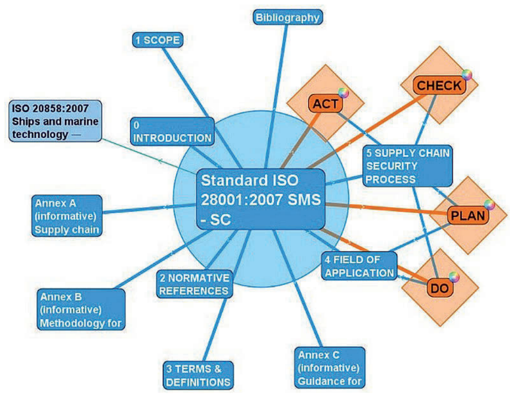
3. Problem Solution

Of course, solving the problem of management systems using visual management is mainly in visual form. The explanations for the individual pictures are more or less complementary. In this form, it is not possible to fully present the dynamics of the model. We will try to give a concise presentation in 2D view.

In Figure 5 there is shown the central node of the created model "Standard ISO 28001: 20017 SMS-SC", this node is connected by means of links to the main clauses of the standard (blue rounded rectangles) from 0 INTRODUCTION to Bibliography. The 4 FIELD OF APPLICATION and 5 SUPPLY CHAIN SECURITY PROCESS clauses are subject to the PDCA (orange diamond shape with multicolour circle) cycle. The relevant standard is ISO 20858 is included on the left.

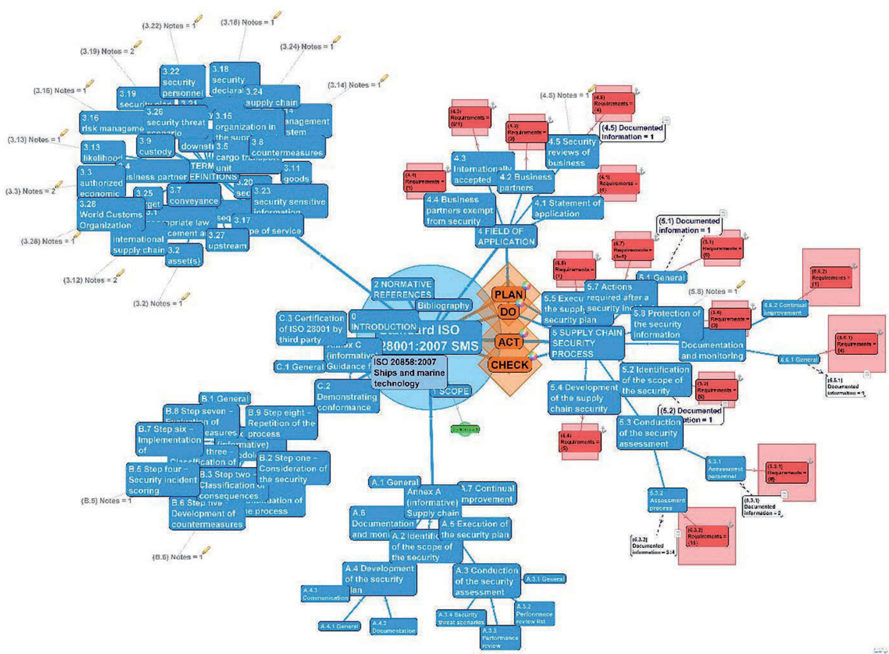
In Figure 6 there is illustrated the final model of the management systems according to ISO 28001 with all nodes that present clauses, subclauses, mandatory requirements (red squares with anchor tag), documented information (white rounded rectangles with white page), notes (with pencil tag).

Figure 5: 1st Degree of Separation for ISO 28001 model with nodes and edges



Source: According to ISO 28001:2007, built by authors

Figure 6: 4th Degrees of Separation for final ISO 28001 model with nodes and edges



Source: According to ISO 28001:2007, built by authors

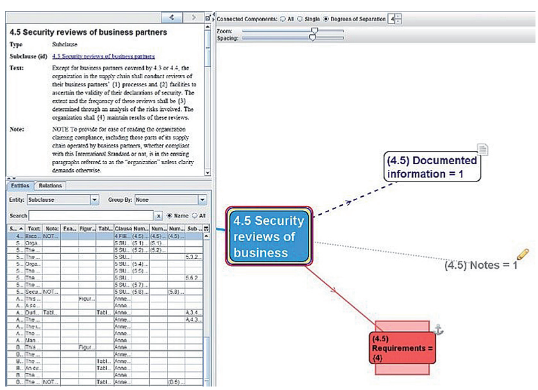
After building the whole model in software TouchGraph, we make a final check of the entered data from the text of standard ISO 28001 Security management systems for the supply chain - Best practices for implementing supply chain security, assessments and plans. After this final check, the model is ready for use by all stakeholders/interested parties.

To better illustrate and express the usefulness of this type of visual management, we have activated the sub-clause (shown on the right) “4.5 Security reviews of business” (blue rounded rectangle), Figure 7. This subclause contains 4 mandatory requirements (red square with an anchor tag), 1 documented information (white rounded rectangle with a white page tag) and 1 note (with a pencil tag).

In the left half of the figure, the entire text of the given clause is quoted in the text field, indicating the mandatory requirements using serial numbers in curly braces. The requirement No. 4 is also documented information.

Below the text of the subclause is an explanatory note for the correct application of the subclause. By activating any node, the relevant information will be displayed in the left field. Which is very useful for examining, implementing, maintaining, improving the management systems according to the ISO 28001 standard for all stakeholders.

Figure 7: Cut-out model with activated “4.5 Security reviews of business”



Source: Authors

4. Conclusion

In this paper, we have presented a possible approach for the visualization of the security management systems standards for the supply chain (SMS - SC). This approach is relatively new and has been applied only a few times. It was a visualization of three management systems according to ISO standards: ISO 9001, ISO 14001 and ISO 20121 and their integration (Pauliková, 2021) and also a visualization of one management systems ISO 46001 (Cvelihárová, 2021). For this reason, it is interesting to monitor what other management systems can be visualized with the help of Small World networks and use software applications to create a 3D model.

The authors used TouchGraph Navigator software, with which they have experience. Here we see how the synergistic effect of several managements allows us to make even challenging issues accessible. In this article there is presented the support provided by visual management for planning, implementing and maintaining a management system according to the lesser-known ISO 28001 "Security management systems for the supply chain –Best practices for implementing supply chain security, assessments and plans – Requirements and guidance". Visual management can work with the dynamic cluster models.

The presented visualized model, using several managements, helps individual(s), team(s), ie all stakeholders who are in a relationship with the supply chain and ensuring its security. This issue is multidisciplinary and covers planning, logistics management, maneuvering technology, product lifecycle management, enterprise asset management and supply chain procurement.

The advantages of this approach are: gaining a general idea of the complexity of the SMS – SM management system, easy orientation in the ISO 28001 standard, quick determination of the number and content of binding requirements and documented information, the ability to obtain additional explanations using node notes, extensive audit assistance for both auditors and audited, if an ISO 28001 clause or subclause is selected as the audit criterion, the possibility to place the model on a website (internal or external), integration with other management systems.

The limitations may relate to access to a software application for visualization of Small World networks, mastering the use of the application, when updating the standard it is necessary to update the data files, correct determination of mandatory requirements (especially for less experienced users of ISO standards related to management systems), correct determination of the number of documented information, duplications may occur during integration with other management systems (Majerník, M.,2021), if a thorough control is not performed.

For further research perspectives, integration with other management systems appears here, e.g. ISO 9001, ISO 19443, ISO 22000, ISO 22163, ISO 22301, ISO 28000, ISO 28002, ISO 28007-1, ISO 39001, ISO 44001 and ISO 55001. Each organization can choose its combination according to its needs and expectations.

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VINdecoder as information tool for eCALL and for VIN data quality analyse

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Abstract

The paper deals with the use of VIN decoder in the pan-European application eCALL (emergency CALL), which provides information about a crashed vehicle in the territory of EU member states online to the nearest PSAP (Public Safety Answering Point) of the Integrated Rescue System. The basic ICT architecture of the solution used in the Czech Republic is described. The crashed vehicle automatically transmits the coordinates of its position, the globally unique VIN (Vehicle Identification Number), the direction of travel on the road, the vehicle category, the number of seat belts fastened in the vehicle (ie the number of people in vehicle) and the system activation flag (automatically or manually). One of the key roles is played by the so-called VIN decoder, which can decode basic information about the vehicle from the VIN structure and provide it to the nearest operational center of the Integrated Rescue System. At the same time, the VIN decoder can analyze the error rate of the VIN item in various information systems, such as the road vehicle register. The authors describe an analytical study, the aim of which was to determine the percentage error rate of VIN in critical infrastructure information systems. An inspection of various information systems revealed that the error rate reached a relatively high value of 8-10 %. The authors describe a way to increase the quality of data in critical infrastructure information systems.

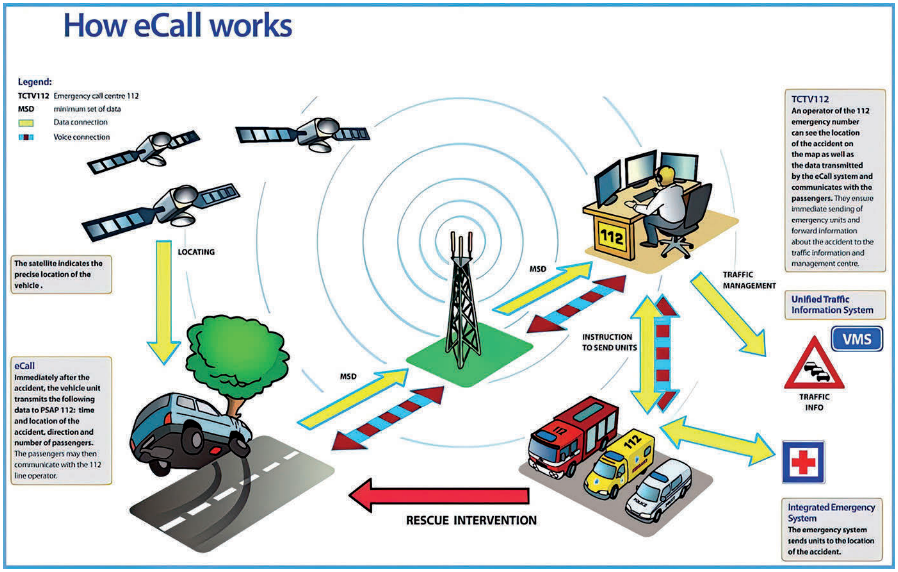
Keywords: eCALL, Vehicle Identification Number, VIN decoder, Critical infrastructure, Vehicle. Emergency

JEL Classification: C88, D81, H56, L98

1. Introduction to eCALL project

One of the main tasks of the European Commission under the name “eSafety” within the flagship program “Intelligent Car” was to launch the so-called eCall project on a European scale four years ago; see Figure 1. The general objective of this project is to provide automatic “emergency”, electronic (“e”) calls for vehicles in the event of an accident or other danger to the vehicle crew to the PSAP (*Public Safety Answering Point*) operations centers of the integrated rescue system 112 (Matouskova et all, 2015; Pavlica at all, 2020).

Figure 1. Scheme of the basic idea of the eCALL project



Source: Matouskova et all, 2015

Each vehicle, homologated after 2018, is located by GPS and basic information about the vehicle in need is transmitted to the PSAP operations center in a uniform telecommunications and data standard binding on the EU through the so-called MSD (*Minimum Set of Data*) standards, which contains location data and time of the accident, telecommunication parameters and the most basic data about the vehicle (*VIN – Vehicle Identification Number)*, vehicle category, fuel used, indication of how the device is activated – automatically or manually, number of seat belts fastened at the time of the accident). Each vehicle is also automatically equipped with a voice communication means ("mobile phone"), so that a connection is immediately established between the vehicle in distress and the relevant operations center via emergency number 112. In this way, anyone in the vehicle crew is able to provide accident details (Kubjatko et all, 2018).

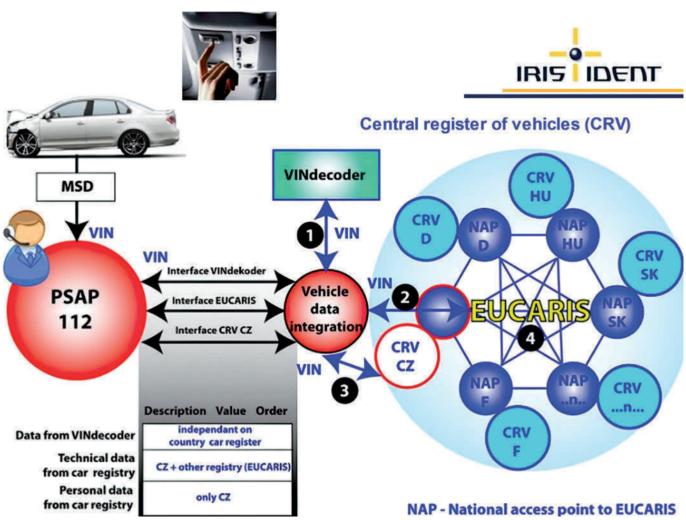
The eCALL project is one of the first pan-European projects to bring digitization into the daily lives of European countries. Of course, this is not only a technical solution, but it is also necessary to ensure the development of managers in the digital environment (Pavlica et all, 2019, 2021).

In addition to determining the position of the vehicle (which is displayed in the operations center on "digital maps") is calculated, for example, mainly in connection with legacy state (government) information systems, i.e. specifically to national (central) vehicle registers and to EUCARIS technology (*European Car and Driving License Information system*). This makes additional technical data on the crashed vehicle available, so that the operations officer is immediately informed, for example, what type of vehicle, category and other technical data (dimensions, weights, etc.) it is and it does not matter where the vehicle originates. The available information is then used for optimization, higher efficiency of intervention units (technical equipment, its quantity, specifics, etc.), so the solution of mass, chain accidents, accidents at night, when there are no witnesses who would help to call for help hard injured or stressed participants in traffic accidents, etc., is automated, ie the vehicle can "help" to call for adequate rescue when the airbags are activated or after pressing the vehicle's emergency button. Information and communication technologies will also help to eliminate language barriers, where many people on the roads have died in the past simply because they have not been able to say their location (Dirnbach et all, 2020).

One of the decisive factors for the technological solution of the entire eCall project, apart from the technologies of telecommunication and data transmission, special SW, is the vehicle identification according to the VIN (*Vehicle Identification Number*).

From the VIN identifier it is possible to find out the basic type identification data of the vehicle (make, brand, basic model, type of engine and its volume, power, body shape, year of manufacture, production plant, etc.) (Ahmed, 2018), (Kolitschova et all, 2018).

Figure 2. Basic architecture of VIN decoder application connection to the eCALL project in the Czech Republic



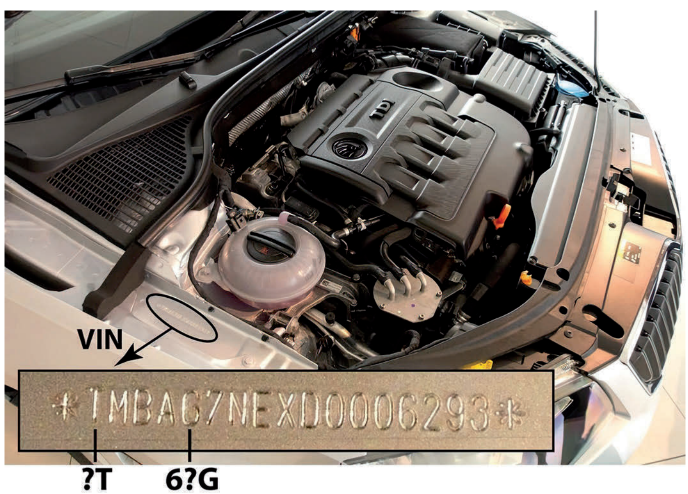
Source: Roman Rak, 2020

At the same time, VIN in the terminology of computer scientists is the only primary identification key for access to other related vehicle records (Bohm,2020), (Rak et all, 2005), from which other necessary data can be obtained – vehicle registration number, its color (which is a very important visual identification mark when rescue services arrive at the scene), dimensions, weights, volumes of transport spaces (to ensure adequate rescue equipment or the necessary capacities for the safe transfer of transported material from the crashed vehicle and removal from the accident site).

2. Issue, target and used methods: VIN decoder as a part of Intelligent Transport System eCall in the Czech Republic

During the discussions, project intentions, initial proposals of the eCall architecture (Figure 2) in the Czech Republic, the question of how to transfer as much technical information about the vehicle as possible to the rescue services from the transmitted vehicle unit to the *Integrated Rescue System* (IRS) operation center was addressed to they had good information for deciding on the composition and technical equipment of the intervening fire brigade. In view of the requirements for a reliable telecommunication connection between the vehicle in distress and the operations center, it has been decided that the transmitted message (MSD) must be as short as possible (Boukerche et all, 2017). With „long", data-intensive transmissions, there is a risk of transmission failure in the field. Therefore, it was not possible to include any extensive technical information about the vehicle in this data report.

Figure 3. Appearance and location of the VIN on vehicles. The VIN is also stored in the eCALL electronic control unit for a vehicle homologated after 2018



Source: Roman Rak, 2021

It was decided to incorporate a globally unique VIN (*Vehicle Identification Number*, Figure 3) into the MSD structure, which on the one hand determines the individual identity of the vehicle, it is possible to read basic information about the vehicle (brand, basic model, category, manufacturer, usually also), body shape and / or engine type, model year, production plant, or other information) and also serves as an interconnection, the so-called database key to various vehicle registers and databases (and further information can be obtained from here) (Dirnbach, 2020). In this way, the condition for reliable data transmission was ensured and at the same time the preconditions for obtaining additional information about the vehicle were created. However, this secondary information is no longer obtained by transmission from the crashed vehicle, resp. vehicles in need (which can be seriously damaged), but from databases that are connected directly to the SW of the operations center. In other words, the source of additional technical-administrative information about the vehicle is not the vehicle itself (it provides primarily to the MSD structure only the VIN, vehicle category and fuel type), but external databases, records, vehicle registers (Rak, 2019, 2021).

During the initial considerations of eCall to ensure vehicle identification, it was also necessary to address the international interoperability of eCall, ie obtaining at least basic information about vehicles in need (Casey, 2014). Considerations were still taking place at a time when the EUCARIS interface for the international exchange of vehicle information was not sufficiently publicly known, and the Internet was not entirely common. The only source of information about the vehicle at that time was only the VIN. Therefore, basic vehicle information was required to be extracted from the VIN.

The method, process of obtaining this information is generally called vindecoding, and the tool itself is a VIN decoder, see Figure 4. The term VIN decoder means a SW tool for online decomposition of the VIN structure of individual vehicles, i.e. obtaining basic information about the vehicle from the VIN, which has been entered into its structure by the manufacturer.

Figure 4. Demonstration of decoding the correct VIN for the Peugeot 5008 vehicle

VF30A5FV8FS097964

WMI OK Decoded (: 0,110 s)

VF3 Peugeot 5008 (0), categ. M1

Family of the vehicle	Peugeot 5008
Body	5 door MPV, 5 seats
Engine	EP6CDT / 5F02 (5FV), 1.6i 156 HP 16V Turbo (1 598 cm3), 115 kW @ 6 000 RPM, L4, petrol
Transmission and emission specification	6MT / 6MTR; (Stop and Start); Euro 5
Model year	2015
Assembly plant	Sochaux, France
Serial production number	097964
Production period	2009 - 2016
VF3	Automobiles Peugeot S.A., Paris, France (passenger car, utility vehicle)
Last global homologation	e2*2007/46*0004*20
Destination region	Europe

Remark

MPV	Multi Purpose Vehicle
HP	Horse Power
16V	16 valves (total)
RPM	Revolutions Per Minute
L4	4 cylinders in line
6MT	6 Manual Transmission
6MTR	6-speed Manual Robotized gearbox
Stop and Start	Stop and Start (engine switching on/off)

Source: Roman Rak, 2020

3. Interconnection of vehicle application using VIN

The exchange of vehicle information between all entities of a national and international nature (which work professionally with cars) in information systems (IS) is carried out only through the world-unique VIN (*Vehicle Identification Number*). It is basically the birth number of the vehicle and during its life (with minimal exceptions) is unchanged, unlike the registration number of the vehicle, which in most European countries changes together with the car owner, in connection with changing the owner's address between territorial units etc. VIN was defined by standards ISO 3779: 2009 (STN ISO 3779: 2013), ISO 3780: 2009 (STN ISO 3780: 2013). These standards are based on standards approved in 1983, ie ISO 3779: 1983 and ISO 3780: 1983.

Current vehicle information checks check information from many reference databases, in which the VIN is usually entered manually. These are national central vehicle registers, information (search) police systems at the national and international level (Schengen, Interpol), information systems of insurance companies, leasing companies, Ministry of Transport, technical or emission control offices, originality or registration checks, executors, services, vehicle dealers, assistance services, etc. In these situations, there is a real danger that the inspection of vehicles from different information sources (with different manual methods of entering VIN) without additional checks on the correctness of VIN, has a potentially high error rate and inspection results may not always correspond to expected reality.

4. Consequences of VIN errors

Due to an error in the VIN when searching the reference databases, the required vehicle is not found. But what does this mean in practice? It depends on how we ask how the negative information about the occurrence of the vehicle is methodically treated when querying the vehicle reference database, how we work with the returned information, what we expect and whether we are aware of any possible negative impacts.

The information "there is no information about the vehicle of the given VIN" means, for example, that the vehicle was not stolen (not in search records), has no information registered to liquidate the insured event at various insurance companies (it was never crashed), is not execution blocked (not in court records), execution blockages), etc. However, if we entered the wrong VIN without realizing it, it means that the vehicle actually appears in these records and therefore we did not receive the relevant information, on the basis of which an incorrect decision was subsequently made. For example, it was wrong to decide on the purchase of a vehicle, securing a financial lease, transfer to another owner, etc. As a result, a considerable amount of damage occurs, so a certain entity is seriously damaged. A vehicle that has been stolen in another country is registered in the national register, the buyer has bought a stolen vehicle or a vehicle on which a court block is imposed, which can then be confiscated by the police or the insurance company repeatedly pays the insurance fraudster a fraudulent traffic accident, etc.

The fact that the error rate in vehicle records is, for example, 10%, does not in fact mean that the resulting error rate is also 10%. If there is a mutual exchange of information between two entities, resp. their information systems (in which, for example, there is a 10% error rate), then there are errors "on both sides" and the yield of information already has a 20% error rate. The error rate adds up. In other words – every fifth vehicle tested has an uncertain, very risky answer!

5. Conclusion – VIN decoder is one of the very effective tools for increasing the quality of VIN

During the eCALL solution in the Czech Republic, the VIN decoder was incorporated into the SW architecture of the project solution as one of the key sources of information about the crashed vehicle for the following reasons:

- VIN decoding time is less than 1 sec. During this time, the operations officer will obtain immediate information on the basic characteristics of the crashed vehicle.
- Obtaining information from the VIN via a VIN decoder does not depend on the quality of the connection to other information systems (central vehicle register), which may be unavailable in some critical situations.
- There may be errors in the 17-digit VIN in the Central Vehicle Register. In this case, there would be no recovery, finding the vehicle in an emergency. Rescue services would not receive any information about the vehicle and its owner or operator. The probability of such an event is almost 8%.
- In the event of a vehicle accident from a European country that is not connected to its national vehicle register via the eCALL module of EUCARIS technology, the rescue services will not receive any information about the crashed vehicle. Currently, only 6 EU countries are involved in the eCALL system from the point of view of international information exchange.
- The VIN decoder is application-independent, and in eCALL technology it is able to cooperate with Russian GLONASS-type satellite systems, so that a crashed vehicle using this technology is provided with the same information support as all EU vehicles.

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Consumer's Concern about Autonomous Vehicles

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Abstract

There is no doubt that automation is an aspect of increasing socioeconomic relevance. The explosion of artificial intelligence in recent years has allowed robotics to perform tasks previously impossible to be automated. Today, artificial intelligence can replace or complement the work of doctors, lawyers, brokers and journalists, revolutionize the management of production lines, increase the efficiency of data centers, deliver products to the door (or window) of the home and, of course, drive cars. The list is growing and brings to light several economic, social, ethical and legal challenges – with which academia and national governments are already dealing, even if in an incipient way. Of the areas permeated by artificial intelligence, autonomous cars attract the most attention, promising a future with an extremely reduced number of accidents, less congestion, practicality for users and less environmental impact. The not-so-distant mass use of self-driving cars will come rich with legal vacuums: Who is responsible for accidents caused by them? Where does the responsibility of drivers and manufacturers end and where does it begin? How to protect drivers' personal data? How should self-driving cars be regulated? What is the role of the government in these matters? In this article, we will briefly address these questions. First, the challenges posed by autonomous vehicles in the Brazilian civil liability regime are explored without further detail. After this exposition, it concludes with a brief presentation of some of the main points of legal attention caused by autonomous vehicles.

Keywords: autonomous vehicles, brazilian consumer's code law, consumers.

JEL Classification: K23

1. Introduction

There is no doubt that companies have made many high-value investments in the market for autonomous systems and artificial intelligence. Even the automobile trade has been a pioneer in technological growth.

Automotive technology systems such as cruise control (known as autopilot), passive and active systems with automatic braking, traction and stability control, automatic parking, etc., are also examples that show the technological evolution. Thus, it is evident the growth of automobile accidents that has been occurring specifically involving autonomous vehicles in tests.

It is important to note that the information available on accidents with autonomous cars that were registered with the government agency does not contain official data on the real reason for the accident. Thus, only the dates of accident occurrences are made available to the public, as well as the name of the vehicle manufacturer/model and a document like an incident report.

In this sense, it is difficult to scientifically evaluate the records available on the site, in order to determine whether the blame for the accident was on the part of the autonomous automobile system or, if the fault was of third parties and, even in the case of concurrent fault, what was the contribution of each of them.

Below is the statistic based on the records of the State of California – USA, whose State has specific legislation requiring that all accidents involving these autonomous vehicles are reported to the competent body.

Table 1. Accident's record of autonomous vehicles in the State of California, USA

YEAR	ACCIDENTS' RECORD
2014	1
2015	9
2016	15
2017	29
2018	75

Source: DMV California Department of Transit – USA, 2021

Importantly, the State of California has specific legislation for testing with autonomous vehicles, including testing with and without the driver. However, it was not possible to find information on how many tests were performed per year, but it appears that the number of companies that are allowed to perform the tests is increasing every year.

It is worth mentioning that every mechanical, electronic and computational system is subject to some failure, be it design, manufacturing or maintenance. In this sense, in the event of an accident with self-driving cars, who will be held responsible? Will it be the vehicle manufacturer, the control system developer, the component supplier, the supplier who just resold it, the mechanic who did its maintenance, the institutions that approved the vehicle for autonomous operation or the owner? There are many questions that can generate doubts and lead to legal uncertainty.

In this sense, the objective of this research is to analyze the civil liability in cases of accidents with autonomous cars, verifying the current legislation and its problem to the application.

To this end, it discusses how the institute of civil liability in consumer relations may or may not affect the damage caused by autonomous vehicles equipped with artificial intelligence. Finally, conclusions are presented.

2. Who is responsible for the damage caused?

Autonomous cars are "self-learning systems": imbued with machine learning algorithms, they learn to make decisions (in this case, to drive) merely by finding patterns in huge data sets and through their own experience. The decisions they make are, therefore, autonomous: they do not depend on the will of both the manufacturer and the driver, and as a rule, being outside the sphere of action and influence of both, they cannot be attributed to them.

Such autonomous decisions, however, can also cause accidents. One can think of the example of one of Waymo's self-driving cars (at the time, still Google): on a road in the United States, the vehicle wanted to veer into the lane on its left. Believing that an oncoming bus would allow him to pass, he changed lanes, then crashed into the bus. The human driver monitoring the vehicle, also believing the bus would pass, did not intervene.

In the United States, there are authors who defend the absence of the need for legislative changes for civil liability for damages caused by autonomous vehicles (Levy, J., 2015), arguing that the civil liability system has adapted with relative success to new technologies over decades. On the other hand, there are those who argue that more detailed legislation is imperative to divide the shares of responsibility between the various actors in the production chain of autonomous vehicles, such as manufacturers, software and hardware producers, among others (Taeihagh, A. et al, 2019).

In the European Union, there are studies that point to the incongruity of attributing civil liability to robots by attributing to them a legal personality of their own (Nevejans, N., 2016). The reasons for this range from the fictitious character of this eventual legal personality, through the displacement of the humanist axis on which the European Union is founded, to the risk of diminishing the status of the human being, which would be being leveled, to a greater or lesser degree, with an artificial intelligence.

As for Brazilian legislation, Artificial Intelligence agents are not yet recognized as individuals subject to law enforcement. This makes them irresponsible for possible damages caused and implies that, according to our legal system, such agents cannot be held responsible for actions or omissions that cause damages to third parties. This does not result in the automatic exclusion of the existence of an eventual (physical/legal) personality of their own.

In this sense, the Civil Code is the greatest expression of private law in Brazil, and it is the law that most closely seeks to meet the demands of citizens. Taking this code as a reference, there is civil liability, which consists of the obligation to repair the damage that one person causes to another.

The theory of civil liability aims at determining the conditions under which the individual can be held responsible for the damage suffered by another person, and the extent to which he is obliged to repair it. Therefore, in any situation in which the person has their rights harmed as a result of someone else's act, they must be compensated in order to compensate for the fact. A major conflict on the issue regarding autonomous cars seeks to identify the civil responsible for an autonomous vehicle involved in an episode that causes harm to a person, and through this it is possible to repair damages between those involved. According to Enrico Roberto:

Even though they are less accident prone than human drivers, eventually self-driving cars will also end up causing damage. Often, such damage will be caused by manufacturing or programming errors, giving rise to the responsibility of the vehicle producer for vice or defect in the product under the terms of the Consumer Protection Code (Roberto, E., 2017).

From the point of view of subjective responsibility, since the decision was taken completely autonomously by the vehicle – regardless of the manufacturer's programming and outside the driver's sphere of action -, one could hardly speak of negligence or omission under the terms of the Civil Code:

Article 186. Anyone who, through voluntary action or omission, negligence or recklessness, violates a right and causes harm to others, even if exclusively moral, commits an unlawful act.

Naturally, in semi-autonomous systems (such as all the cars sold so far), in which the autonomous performance of the vehicle is interspersed with human intervention at critical moments, one may speak of negligence or omission if the driver fails to intervene when the vehicle demands it through sounds and lights, for example, or when failing to intervene in clearly dangerous situations:

Article 927. Anyone who, by unlawful act (articles 186 and 187), causes damage to another, is obliged to repair it.

From the point of view of strict liability of the manufacturer, it should be noted that the autonomous decision taken by the vehicle cannot be a defect in the product.

Article 18. Suppliers of durable or non-durable consumer products are jointly and severally liable for defects in quality or quantity that make them inappropriate or unsuitable for the consumption for which they are intended or which reduce their value, as well as for those resulting from the disparity, with the indications constants of container, packaging, labeling or advertising message, respecting the variations resulting from their nature, and the consumer may demand the replacement of defective parts.

On the contrary, the ability to make independent decisions and learn from one's own experience is exactly what makes such products economically attractive and, for many authors, exactly what characterizes them as "artificial intelligence". Likewise, it is difficult to argue that this is a product defect under Article 12 et seq.:

Article 12. The manufacturer, the producer, the builder, national or foreign, and the importer are liable, regardless of the existence of fault, for the repair of damages caused to consumers by defects arising from design, manufacture, construction, assembly, formulas, handling, presentation, or packaging of its products, as well as insufficient or inadequate information about their use and risks.

These defects are related to what is known today as "development risk" and which is widely addressed in the literature by Marins, J., (1993), Benjamin, A. H. de V. et al. (1991), Gomes, M. K. (2001), Almeida, J. B. (2000), and Policarpo, N. S (2012). There is no global consensus on the subject, and in Brazil there are two distinct currents: (1)

in favor of the risk of development as an exclusion of supplier liability; (2) in favor of supplier liability. Thus, it is still debated whether the unpredictable defect is an illicit act that violates a legal norm.

Similar to software bugs, which to some extent are unavoidable, autonomous decisions have an inherent risk that cannot be completely extinguished. In this sense, one cannot "legitimately expect" that they will never cause harm.

A self-driving car is naturally expected not to actively cause accidents; what cannot be demanded is that it should be entirely exempt from them. The current law does not make it clear who will be liable for damages caused in the accident of self-driving cars. Would there be an answer if the car was, for example, over the speed limit? Or if the collision was between two autonomous cars? There appears to be, in several cases, a loophole in the law.

However, the Consumer Protection Code was designed to recognize the vulnerability of the consumer in addition to ensuring that safe products are available on the market for use. The Consumer Law Code of Brazil, when referring to the prohibition of making products available on the market that in some way may bring risks.

Such mandatory safety compliance is further detailed in Chapter, Section I "Health and Safety Protection". Thus, it is understood that all tests and operational situations to which autonomous systems will be submitted must be foreseen in their algorithms to meet the requirements for placing the product on the market.

Article 8 Products and services placed on the consumer market will not pose risks to the health or safety of consumers, except for those considered normal and predictable because of their nature and enjoyment, with suppliers being obliged, in any event, to provide the information necessary and appropriate for you. § 1 In the case of an industrial product, the manufacturer is responsible for providing the information referred to in this article, through appropriate forms that must accompany the product.

Thus, to manage the risk inherent to autonomous cars, some authors have advocated, for example, a new type of strict liability based primarily on the notion of "danger creation". It will be up to the academy and the courts to determine the limits of such a notion of responsibility, as well as the extent to which it would in fact be legally necessary or socially relevant.

Finally, it is worth highlighting the study carried out by the department of the Federal Senate that discusses the "Considerations on Autonomous Vehicles – possible economic, urban and legal impacts":

Current legal tools are only partially prepared to face this situation. It is that, according to the theory of custody of the thing, whoever holds the power to direct that thing must answer for the damages resulting from its use. This is a consequence of the theory of risk-created: whoever securitizes an object potentially generating harm to third parties must assume the burden of this risk that it created itself. It follows that, in these cases, it is irrelevant to investigate the existence of fault on the part of the owner of the thing, since liability is objective (Oliveira, C. E. E. and Leal, T. A. C. B., 2016).

The duty to ensure safety belongs to all those who help to introduce a product on the market, but there will only be a violation of this duty, giving rise to the responsibility to repair the damage, when there is a defect in the product, however, if the defect does not exist, there will be no obligation to repair (Maia, M. M., 2017).

3. New Challenges

The implementation of such innovative and revolutionary technology as self-driving cars has brought legal challenges that are still difficult to imagine, and it is still unclear what the role of public authorities should be in this context. Some educated guesses, however, can be made.

Many of the challenges are eminently technical. To what extent should producers, for example, be able to explain how their vehicles work? What are the technical rules that must be followed in its manufacture and operation? The answer to these questions can even resolve civil liability issues, for example, by drawing technical boundaries between what can be considered an "addiction" and what is a mere "autonomous decision". It is understood that it would be necessary to create specialized regulatory agencies to deal with such problems, which in some situations could find support in Brazilian law.

Another viable mechanism to reduce the risks inherent to this technology is the creation of mandatory insurance contracted by manufacturers. Considering the large-scale inevitability of damages and the difficulty of predicting them or determining their causality individually, the imposition of compulsory insurance could also, at least in part, have positive effects. Another relevant role that regulatory agency could play would be in determining the scope and necessity of such measures.

However, agencies cannot be the only ones to regulate the issue of autonomous vehicles. There are other legal problems that go beyond technical issues and will depend on legislative activity. One of the most relevant is the protection of driver data. With automation, more and more data will be collected from drivers; and not only from where and where they go, but about the most diverse aspects of their surroundings, since such data are necessary, for machine learning algorithms, for the vehicle itself to improve its driving ability. Even though it is still not clear at what level such collection (and eventual sending to the manufacturers' servers or third parties) will be necessary and possible, some problems already present themselves in advance: This collection will be allowed to what level? In what ways can it be abused by companies, and what is the role of the law in this potential abuse? Who are the holders of this data? Will they be able to be sold to other companies? If yes, under what conditions?

This data would be an essential element for the proper functioning of autonomous cars – and even of any other systems imbued with artificial intelligence. They have a growing economic and social value not yet fully realized, but with the increasing implementation of such systems it will become increasingly clear.

4. Final considerations

Autonomous cars are still a new frontier for Brazilian law. The law is still not able to satisfactorily manage the risks that will gradually become clear with the mass use of new technology, giving only partial answers to the most important questions imposed by it.

From the point of view of civil liability, the autonomous performance of the vehicle challenges both the notions of subjective and objective liability. This is because, to a certain degree, it is outside the sphere of influence of manufacturers and drivers, however, such autonomy (and its inherent risk) is a desired and expected element of such systems. The problem is compounded by the black box of artificial intelligence, the difficulty of explaining whether the internal processes of autonomous vehicles lead them to make the decisions they do.

In addition, several other challenges present themselves. Future regulations will have to deal with the technical aspects of the manufacture and use of vehicles, with possible risk containment measures, such as the imposition of mandatory insurance, as well as with the protection of the (increasingly valuable) data obtained. from the use of autonomous vehicles.

Finally, it is emphasized the need for standardization, ranging from system component manufacturers, software developers, assemblers, dealers, workshops and even owners must be governed by obligations and responsibilities expressly in legislation, reducing maximum subjectivism about the obligation to indemnify.

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Environmental sustainability: the possibility of overload of electrical vehicles on power grid

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Abstract

As pollution is increasing resulting in greenhouse gases and global warming the number of electric vehicles will increase. The inevitable energy crisis is one of the key reasons why green and renewable fuel technologies have advanced; but since the early 1960s, this transition has been promoted by the environmental lobby. Minimize emissions is a big tactical path for sustainable growth in the industry. These electric cars need to be recharged in evening or night, so the electric vehicles will demand more of the power grid during this period. This process will impact the network voltage profiles and loading of grid elements. Existing Grids were designed several decades ago, so will it be able to support this increased loading? Injection of electrical vehicle into the grid will also have an impact on power factor. As some consumers turn on or off their electric vehicles, the overall power factor changes. This must be considered as this impact the reactive power consumption. With increase in the number of electric cars, the loading characteristics of transformer changes. Will this be considered by the power plant or is it necessary to stablish a law to prevent this side effect?

Keywords: environment, power grid, electric cars, sustainability law

JEL Classification: K23

1. Introduction

Electric mobility is advancing in the world's major nations, such as China, the United States and the countries of the European Union such as Great Britain, Norway, The Netherlands, Germany and France. With a view to the global goals of decarbonization of the economy, these states focus on regulating the sector to create incentives not only for the consumption of these vehicles, but also for the improvement of the infrastructure and technology involved.

The recent climate changes and global warming forced human beings to find alternatives to fossil fuels (Abo-Khalil *et al.,* 2022). Although progress made in using renewable energy sources in several applications (Źabnieńska-Gora *et al.*, 2021) still not commonly used in the transportation sector that represents one of the main pollution sources. For many decades, vehicles powered by internal combustion engines (ICE) have dominated the car market because of great autonomy and low cost; factors that led them to consolidate a market without competitors. For decades, companies have been investing many resources in developing improvements to this technology. Another important factor is that consumers are used to using vehicles powered by ICE, making it more difficult to insert electric vehicles on the market, especially when the prices of these cars are higher than those of conventional vehicles (Das, H Rahman, S. & Tan, Li C., 2020).

With the growth of the world vehicle fleet, the emissions of exhaust gases from the transport sector started worry authorities, both in the climatic phenomenon called global warming and in the air quality, being an aggravating factor to the respiratory system of citizens (Das, H Rahman, S. & Tan, Li C., 2020).

Carbon dioxide (CO2) is the main gas emitted by combustion engines, and due to incomplete combustion, methane (CH4) is also emitted. These gasses are proven to be responsible for global warming, with methane about 20 times more harmful than carbon dioxide (X. Sun, Z. Li & X. Wang, C. Li, 2020).

Carbon monoxide (CO), nitrogen oxides (NOx) and sulfur (SOx), aldehydes, particulate matter (MP), and unburned hydrocarbons (CxHy), form smog and contribute to the degradation of the quality of the air. Therefore, measures to reduce gas emissions in this sector are one of the main ways to combat global warming and deteriorating air quality (Badr, O; Probert, S & O'callaghan P., 1991).

In transport, the best way for reducing fossil fuels are expected by adopting electric and hybrid vehicles. In the roadmap of International Energy Agency (IEA), an introduction of electric vehicles and plug-in hybrids is envisioned so that they reach 50% of light vehicle sales in 2050 (IEA, 2021) The relevance attributed to these vehicles in the context of a transition to an economy of low GHG emissions is associated with greater energy conversion efficiency (IEA, 2021).

The greater efficiency of electric vehicles compared to conventional vehicles is mainly associated with the fact that the conversion efficiency in the electric motor (that is, from the battery to the engine) is very close to 100% while, in the internal combustion engine, this efficiency is in around 30–40%. There are purely electric vehicles – battery-powered vehicles, or BEVs – and also vehicles that combine electric propulsion with traditional engines, called hybrid vehicles (HEVs) or plug-in hybrid vehicles (PHEV), depending on how the battery is recharged (Vidyanandan, K.V., 2018).

The first EVs were conceived in the 1830s, a few decades after Alessandro Volta (1745–1827) demonstrated the possibility of chemically storing electrical energy in batteries. The first vehicle to apply this battery was a tricycle developed by Trouvé in 1881 (Desmond, 2016). Between 1880 and 1900, electric vehicles lived a golden age. However, at the beginning of the 20th century, electric vehicles competed in the market with vehicles powered by ICEs (Henry *et al.,* 2020) From the 1920s onwards, the primacy of gasoline vehicles became clear and electric vehicles lost strength in the market. The reasons given for the success of gasoline vehicles (and the consequent decline of electric vehicles) are diverse (Singh *et al.,* 2019) and indicates the following factors:

- The reduction in the final price of the gasoline vehicle (Ford T), from the development of the series production system, by Henry Ford
- The invention of the electric starter in 1912, which eliminated the need for the crank to drive vehicles with ICE
- The developed US highway network, which in the 1920s interconnected several cities, required vehicles capable of traveling long distances
- The drop in the price of gasoline, made possible by the oil discoveries in Texas that reduced the price of gasoline, making it an attractive fuel for the transport sector.

In recent years, EVs have been regaining space, being seen as a viable alternative to address the issues of local and global air pollution, and the use of non-renewable resources. The advantages of electrified vehicles over conventional vehicles include greater efficiency, lower pipe emissions, less noise, greater driving comfort, etc. (IEA, 2021). While there are only 17,000 EV in 2010, the number increased to 7.2 million EVs in 2019. Currently in more than 20 countries, the EVs share with more than 1% in their EV market. Figure 1 shows the exponential change of the EV market in the last decade indicating the fast growth of this market (IEA, 2021).

2. Electric Vehicles and the Environment.

Research has shown that electric cars are better for the environment. They emit fewer greenhouse gases and air pollutants than petrol or diesel cars. And this considers their production and electricity generation to keep them running. The major benefit of electric cars is the contribution that they can make towards improving air quality in towns and cities, making them a better place for pedestrians and cyclists. With no tailpipe, pure electric cars produce no carbon dioxide emissions when driving. Just one electric car on the roads can save an average of 1.5 million grams of CO2. This reduces air pollution considerably (ICCT, 2018).

UK government has set a target that the sale of petrol and diesel cars will be banned by 2040. The government is also looking to reduce carbon emissions to zero by 2050, and electric cars will play a big role in that. EVs can also help with noise pollution, especially in cities where speeds are generally low. As electric cars are far quieter than conventional vehicles, driving electric creates a more peaceful environment for us all (Mayor of London, 2020).

Making electric cars does use a lot of energy. Even after taking battery manufacture into account, electric cars are still a greener option. This is because of the reduction in emissions created over the car‘s lifetime. The emissions created during the production of an electric car tend to be higher than a conventional car. This is due to the manufacture of lithium-ion batteries which are an essential part of an electric car. More than a third of the lifetime CO2 emissions forma an electric car come from the energy used to make the car itself. As technology advances, this is changing for the better (ICCT, 2018).

All this shows that electric vehicles have a big role to play in reducing transport emissions and being a major factor in cleaning up the air we breathe.

3. Electric Vehicles and the Power Grid

For our transport systems to be completely electric, the existing infrastructure needs to be expanded to enable all the vehicles to be recharged. And new charging points are just the tip of the iceberg: Ultimately charging requires a vast amount of power. At a present-day quick-charge station with a charging capacity of 150 kilowatts. If huge numbers of vehicles suddenly ran on electricity alone and made use of quick-charge facilities, that would put huge stress on our power networks. Some of our existing power networks would be simply overloaded if millions of vehicles were to switch to battery-only operation overnight and had to be recharged in a matter of minutes (Lee, Henry & Clark, Alex, 2018).

Electromobility poses a double challenge for distribution system operators: First, EVs add to the number of consumers. The more EVs that are charged at the same time, the more likely it is that the grid will be overloaded. Second, electromobility is only environmentally practical if the required electricity comes from renewable sources. But wind and solar power have the problem of being irregular, and most wind turbines and sizeable solar power plants are in rural areas, while most of the power is consumed a long distance away in cities. Urban distribution systems will have to be able to establish a balance between large volumes of power from decentralized and irregular generation sources in the future (Vilathgamuwa *et al.*, 2022).

The expected growth of the market will be important for decades. The scenario that specialized firms and opinion leaders in the sector sets for the year 2040 is: a) Long-term EV sales will be influenced by how quickly the charging infrastructure spreads across key markets; b) Buses will go electric faster than light vehicles; c) EVs will save 7.3 million barrels/day of fuel in the transportation sector; d) The new scenario on electric mobility will have a great impact on the automotive industry, environmental conditions, and the electric power sector.

To support the adoption of EV, there is a need to implement infrastructures for charging stations. The charging standards and infrastructures for that purpose and that are available have a great impact on how people use or may use EVs and, consequently, have an impact on how these vehicles penetrate the market.

4. Global Sales of Electric Vehicles

Many European countries, USA, China and Brazil are quite active in promoting their use and investing heavily in electric mobility. In Europe, Norway, The Netherlands, The United Kingdom, Germany, and France are the leading countries. The infrastructure needs to grow as more and more electric vehicles appear on our roads. If 80% of all cars were electric in 2050, the Europe's electricity consumption would probably go up to 10%. The electricity grid will also need to evolve as more electric cars hit the road (Aijaz & Ahmad, 2021).

No cars will be 100% clean. The arrival of the electric car doesn't change that. Using public transport or simply walking or cycling to work will always be much better for the environment. Electric motors are more efficient than combustion engines and waste less energy. Electric vehicles can also bring down noise. Heath-wise, the main benefit is related to air quality. The EU has been channeling billions of euros into relevant research over the last decade and *is pushing for a rapid expansion of the charging infrastructure. It is also investing heavily and promoting alternative fuel infrastructure, which includes electric vehicle chargers, especially on the main European transit corridors (Sioshansi & Webb, 2019)*

Tesla, the world's most valuable automaker by market value and a leader in electric car sales, delivered 936,000 vehicles in 2021, nearly double the number by 2020. The world's leading car manufacturers are betting on the segment. The projects of cars powered by electricity range from the United States, with Ford and GM, pass through Europe, like Volkswagen, and reach Asia, with Nissan, Hyundai, among many others (Richter, 2022).

But it's not just automakers that are keeping an eye on the electric car market. Five cell phone manufacturers are betting on clean energy vehicle projects:

i. **Apple:** for nine years Apple develops the Titan project, a standalone electric car expected to be launched by the end of this decade. The vehicle may come without pedals or steering wheel: the car would be driven only by the automatic driving system. To get out of the paper, Titan needs a partnership with an automaker.

ii. **Xiaomi**: electric vehicle division was created only in 2021, but the Chinese company's plans are ambitious. Lei Jun, the company's CEO, is also responsible for a team of 300 employees who are developing the electric-powered car. The company plans to invest $10 billion over the next decade in the segment. Xiaomi also rushes to put on the streets its first electrified model until 2024. The company made the acquisition of DeepMotion, a Chinese startup specialized in autonomous driving, to assist in the progress of the project.

iii. **Sony:** electric vehicle is geared towards entertainment. (Source: Sony/Play) Source: Sony/Play. Sony has already introduced two concept vehicles powered by electricity. At CES 2022, in addition to presenting a new SUV, the Japanese company introduced Sony Mobility, which will dedicate itself exclusively to the electric mobility sector. The Vision-S 02 is a functional prototype with 40 safety sensors and 5G connection possibilities. Still no date to be released, the vehicle uses the same platform as the prototype unveiled two years ago, which is being tested on public roads. The new prototype can house up to 7 passengers and features customizable panel configurations, acceleration sounds and key locks. The Vision-S 02 even has a large dashboard that can be used for video streaming and even playing PlayStation with a remote connection.

iv. **Oppo:** China's Oppo announced in late 2021 that it is entering the automotive business with a platform called Carlink. The solution aims to completely digitize the driving experience, from the use of digital keys, which have a slow uptake, to resources that can be controlled remotely by the owner. In addition, Oppo wants to launch its own electric vehicles and autonomous cars, starting with the Indian market, according to information from the 91mobiles website. The launch is scheduled for late 2023 or early 2024.

v. **Huawei:** Aito M5 with Huawei's operating system will begin to be delivered in February. (Source: Huawei/Play) Source: Huawei/Reproduction . Huawei does not intend to manufacture electric cars on its own but has been collaborating with several automakers with automotive technologies such as autonomous driving. The first vehicle that will feature the HarmonyOS operating system, developed by the company in 2019, will be the Aito M5 hybrid. Car prices will be subsidized and cost from 250,000 yuan (about $39,000), just below Tesla‘s Model Y, which is sold from 280,000 yuan under the same conditions. According to Huawei, the Aito M5 offers better peak power and autonomy than Elon Musk‘s company car. Deliveries begin in February, just after the Chinese Lunar New Year holiday, giving an idea of what we can expect for the company‘s future in the segment.

5. Regulating electric mobility in Brazil

Even with the crisis caused by the pandemic, 2020 brought considerable advances for electric mobility in Brazil. According to the Brazilian Electric Vehicle Association (ABVE), there was a 66.5% increase in plaques compared to the previous year. However, despite the good numbers, more incentives are needed to promote and facilitate the adoption of electric vehicles in the country. In Europe, for example, the EU expects to reach 30 million electric units by 2030. To this do so, countries are betting on incentives not only economic and fiscal, but also regulatory and directed to recharge infrastructure.

The sale of electric vehicles had the best quarter of the historical series and recorded the plate of more than seven thousand units, according to ABVE. The entity predicts that the national market should exceed the mark of 28,000 vehicles in 2021 alone – a number that, according to other projections, can exceed 35,000. The Energy Research Company (EPE) predicts that the pace of sales will accelerate to up to 180,000 units sold per year by 2030, reaching a total of 1 million electric vehicles. For this, however, it is necessary to continue betting on the regulation of electric mobility to generate new incentives.

As we commented, in Brazil, although embryonic, there are important measures for the regulation of electric mobility. We highlight:

i. Resolution No. 97/2015: instituted by the Chamber of Foreign Trade (Camex), determines the reduction from 35% to zero of the import tax rate for electric cars or fuel cell-powered cars. The cut also includes hybrid vehicles, with a reduction of 2% to 7% (Brazil, Resolution, 2015)
ii. Law No. 3,755/2018: creates the Rota 2030 Program, a set of federal government guidelines that includes, among other things, energy efficiency targets for combustion vehicles and incentives to produce electric and hybrid cars (Brazil, Law, 2018).
iii. Decree No. 9,442/2018: reduces the IPI rate on electric vehicles from 25% to 7% and hybrid vehicles from 25% to 20% (Brazil, Decree, 2018).
iv. Normative Resolution No. 819/2018: instituted by the National Electric Energy Agency (ANEEL), dictated on the regulation and recharging of electric vehicles for any companies and people interested in the provision of this service, with freely negotiated prices (Brazil, Resolution), 2018.

v. Ordinance No. 2,519/2019: instituted by the Special Secretariat of Productivity, Employment and Competitiveness (SEPEC), defines the following priority programs: Leverage of Alliances for the Automotive Sector, R&D for Mobility and Logistics, More Competitive Brazilian Tools, Development of Technologies in Biofuels, Vehicle Safety and Alternative Propulsion to Combustion, FINEP 2030 and R&D and Engineering for the Automotive Sector Production Chain (Brazil, Ordinance), 2019.

In addition to the measures already mentioned, Brazilian Bill No. 3174/2020 is being processed in the House of Representatives, which establishes federal policies to stimulate the use of vehicles powered by electric and hybrid propulsion. In the Senate, in the wake of measures announced by countries such as China, the United Kingdom, France, India and Norway. The Brazilian Bill No. 304/2017 was introduced to ban the sale of cars to fossil fuels by 2030 and their circulation by 2040.

With regulatory incentives, Brazil has the potential to become one of the main markets for electric mobility, generating opportunities for companies that want to invest in research incentives to explore this technology in an increasingly efficient way.

6. Conclusion

Electric vehicles are being considered as an alternative to solve or decrease the current environmental issues. It can be said that the starting point of the spread of electric vehicles was the government regulations to overcome the environmental issues. The growth of electric vehicles can be interpreted as heralding a revolution in transportation and power, and energy infrastructure.

The charging infrastructure for electric vehicles are rising to accommodate the spread of the electric vehicles. It is necessary to build an efficient and intelligent electric vehicle charging infrastructure that can respond to electric power supply and demand. Major overseas countries in the electric vehicle/hybrid industry are promoting charging infrastructure supply policies in consideration of their own industries and environmental conditions in line with the expansion of electric vehicle supply. Although there is still a lot to be done until the complete dissemination of technologies, the research in the smart recharge of the EVs indicating that the increasing in the number of the EVs can be adapted and regulated to maintain the stability and high performance of the grid and a safe and healthy environment for us all.

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Workplace design in the conceptual phase in VR with ergonomics verification using MoCap

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Abstract

The paper consists of innovative solutions for workplace design, optimization of work activities, and creation of work instructions using digitalization in the context of the industry 4.0 concept. The aim is to create a 3D model of the workplace, on which compliance with ergonomic and safety limits according to Czech legislation will be verified. During production, errors and shortcomings often occur, which can manifest themselves in waste in the production process, deteriorated product quality, and health problems of workers. Any interventions in an existing workplace entail high costs for changes. Thanks to the above approach, it is possible to identify deficiencies already at the pre-production stage, eliminate them with the right technology and design solutions and thus achieve significant financial savings for both manufacturing and non-manufacturing companies. Ensuring appropriate ergonomic working conditions ensures the elimination of occupational disease risks for workers, the protection of employees, and the associated costs.

Keywords: ergonomics, mocap, motion capture, virtual reality, workplace design

JEL Classification: L590, L600, L690, L790

1. Introduction

The paper consists of innovative solutions for workplace design, optimisation of work activities and creation of work instructions using digitalisation in the context of the industry 4.0 concept. The aim is to create a 3D model of the workplace, on which compliance with ergonomic and safety limits according to Czech legislation (NV 361/2007 Coll.) is verified (Battini et al., 2011).

The idea of the methodology was conceived while studying at the University of West Bohemia in Pilsen, Faculty of Mechanical Engineering and while working on projects for industrial enterprises. Due to the pressure exerted on companies in terms of ergonomic limits, it was necessary to focus on the ergonomic aspect in the projects (Menolotto et al., 2020)such as visual cameras and inertial measurement units (IMUs. Working on a workplace model in virtual reality will significantly save the cost of machine acquisition and possible changes. The methodology procedure is standardised and can be applied repeatedly according to customer demand (Menolotto et al., 2020) such as visual cameras and inertial measurement units (IMUs).

2. Design procedure

Based on the customer's data, a workplace model is created in a virtual environment (Unity platform). This model corresponds to the design of a real workplace in the conceptual phase. The workplace in VR is prepared and adapted to allow changes within the spatial arrangement and layout, within the equipment used and its placement or within the working environment. This allows the use of VR in the design phase of the workplace, during which changes are usually made. One area of change is to adapt the workplace from an ergonomic point of view in order to reduce the difficulty of the work performed, improve working conditions, eliminate occupational disease risks and increase worker productivity. For this purpose, motion capture technology is used, which makes it possible to capture individual movements of the measured person using sensors placed on the body.

As part of the measurement, the proband is dressed in Motion Capture technology. Figure 1 shows the preparation of the proband for measuring and fitting into the MoCap suit for the simulation in VR. Everything is connected to a powerful computer.

Figure 1: Preparation phase

Source: Authors, 2021

The measurement itself takes place on a virtual model of the real or future state of the workplace. Proband puts on a virtual reality headset, in which the process simulation is run. The Proband performs the individual operations and at the same time the values from the Motion Capture suit are recorded in the corresponding software.

After the simulation using the kinematic suit, the workplace is tested according to the established ergonomic limits. Subsequently, the data will be processed and evaluated. Then critical parts of the process are optimised, and standards are updated.

2.1 Kinematic suit measurement

By using virtual reality technology and creating a virtual model of the workplace, it is possible to simulate real activities already in the phase before the actual implementation in production (Soussé et al., 2020). The innovative approach in this direction follows the trend triggered by the Czech legislation, which sets the conditions for occupational health protection. One of the conditions is the breakdown of risk factors of working conditions, their detection and evaluation of physical load in relation to working positions. This evaluation establishes a categorisation of work that defines the probable adverse effect on the worker's health (Nagymáté et al., 2018).

A person performing real activities on a workplace model is dressed in a Motion Capture kinematic suit that transfers real movements into a virtual environment (Li and Zheng, 2021). The suit records real-time data on the worker's movement (Gregor et al., 2015). This data is subsequently recalculated and evaluated using a created application respecting the set parameters according to the Czech legislation. This involves the evaluation of the position of the neck, torso and upper limbs when performing working task. For a more detailed evaluation, the neck and trunk movements of the worker can be divided into flexion/extension, abduction/adduction and rotation. The movement of the right and left shoulder can similarly be divided into flexion/extension and abduction/adduction. Using the developed tool, measured positions are classified according to Czech legislation into acceptable, conditionally acceptable and unacceptable positions, with a limit of 160 minutes per eight-hour shift in the conditionally acceptable position and 30 minutes in the unacceptable position (Ministerstvo zdravotnictví [online], 2022). Due to the large volume of recorded data (up to 120 frames per second), higher accuracy and objectivity of measurement is achieved compared to classic workstation design approaches (classical goniometer). The application evaluating the measured data provides an overview of the ergonomic suitability of the solution and highlights the shortcomings in the workstation design. The standardization of the evaluation parameters by the application eliminates the need for an ergonomics specialist and as a result, time and financial savings are achieved (Azizi et al., 2019).

2.2 Workplace model optimization in VR

The virtual reality workplace model allows you to test changes in the workplace concept and adjust its parameters to achieve ergonomic improvements (Delangle et al., 2017). Thanks to these possibilities, it is possible to identify problem areas in the process and optimize them in the workplace model (Azizi et al., 2019). At the same time, potential costs linked to additional modifications to an existing workplace are avoided.

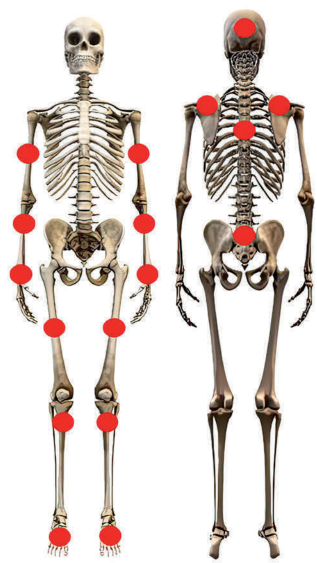
The virtual reality workplace model is further linked to the creation of workplace standards and work activities. At the same time, the model can be used to train workers when they start a job (Feldmann et al., 2019).

3. Methodology progress

At the beginning of the methodology procedure there is firstly the customer's input data and documentation analysis. Using this data, a virtual workplace model is created on the Unity platform. The model is supplemented with a workplace standard and workflow. Then the worker is dressed in a kinematic suit from Noitom, which is completed with a VR headset (HTC Vive Pro) to simulate the real workplace. Measurements using the suit can also be taken in the company's real workplace.

The suit consists of 17 sensors that are placed on the proband's head, torso, arms and legs. These sensors are used to capture real human movements. The movements are converted in real time to a digital model on a computer. The location of the sensors is shown in Figure 2.

Figure 2 – Sensor placement on the body

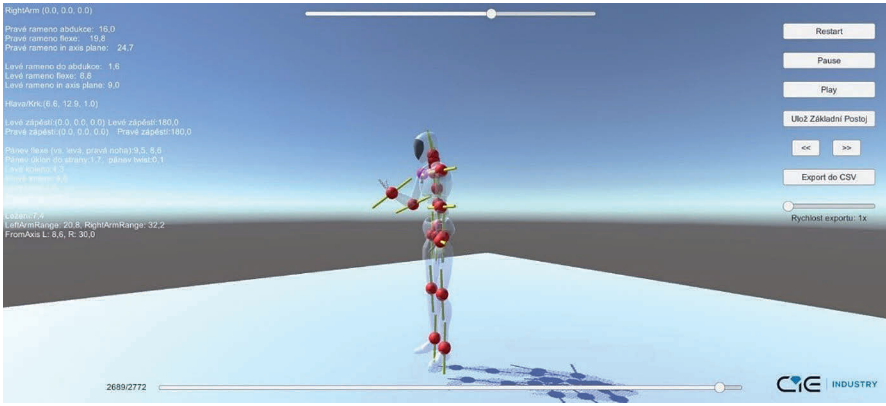


Source: Authors, 2021

The Motion Capture suit allows to measure and record ranges of body part angles at each moment according to defined frames per second (fps). This value depends on the initial input and desired accuracy. There are ranges from 30 fps to 120 fps. As the value increases, the complexity of the evaluation increases. The virtual reality workplace model allows the measurement and testing of realistic tasks in a non-existent workplace. After combining these technologies, the designed workplace can be further improved or optimized not only ergonomically.

The movements are recorded using Axis application which is compatible with MoCap suit. Values in each frame are converted into created Unity application, which is used to export the data in text format. Before starting the measurement, the frame rate, called the measurement rate, is set, and the number of frames is directly proportional to the measurement rate. Figure 3 shows the virtual environment in Unity.

Figure 3 – Unity Hub application



Source: Authors, 2021

For the evaluation of the measurements, a tool working on the MS Excel platform was created and supplemented with the required functionality using Visual Basic for Application (VBA) code. This tool allows to process a large amount of data according to predefined parameters and evaluate them at the same time. The output, as can be seen bellow, is a tabular and graphical representation of the total percentage of critical body positions. This gives an initial indication of whether the workplace is ergonomically suitable or whether optimization is needed.

Using a tool for evaluating large volumes of data, the results are compared with the limits set by Czech legislation or with the company's internal standards. The partial output is the number of frames in acceptable, conditionally acceptable and unacceptable positions. The next step is to create a graphical visualisation of the percentage of positions relative to the total number of frames for the selected body parts. Figure 4 illustrates the auxiliary tool for evaluating the positions according to the legislation.

Figure 4 – Evaluation tool

Source: Authors, 2021

Another possibility of the tool is also the identification of specific critical tasks or operations. Given a certain number of records per second, a comprehensive view of the specific task performed is created and by recalculating the real time, it is possible to find the specific moment in which the position of a body part was ergonomically unsuitable. This approach allows the optimization to target specific performed operations that do not meet ergonomic standards. These individual operations or activities are further analysed and modified with the aim of ergonomic improvement.

If the set limits are exceeded, it is necessary to speak about an adverse effect of the working positions on the health of the worker. Measures must be designed to reduce unacceptable positions to a minimum. This may involve changing the ergonomic layout of the workplace, acquiring suitable equipment, changing the working procedure, etc. In the case of virtual reality workplace design, optimisation can be carried out after testing the workplace and the costs associated with modifying the real workplace can be avoided.

Once the appropriate measures have been taken and the ergonomic optimisation has been carried out, the virtual reality model is also redesigned. This new state of the model is then validated and verified to see if further iterations are needed or if the workplace is ergonomically suitable. A workplace that is validated as ergonomically suitable can then be implemented in real life.

4. Conclusion

By using modern technologies, which consist in creating and testing a virtual model of the workplace and motion sensing, it is possible to detect deficiencies already in the pre-production phase. With the right technological and design solutions, shortcomings can be minimised, thereby achieving significant financial savings for both manufacturing and non-manufacturing companies. Optimising the workplace in terms of ergonomics serves to increase safety, make work easier to perform and reduce worker fatigue, leading to increased productivity and the elimination of occupational diseases.

Working on a virtual reality model of the workplace saves considerably on acquisition costs and possible changes. The methodology procedure is standardized and can be applied repeatedly according to customer demand. Software for the evaluation of ergonomic measurements is currently being developed. Over the years there will be continuous development and refinement of the virtual reality workplace design method using MoCap to increase the efficiency of methodology progress.

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Autonomous systems, the future of industrial logistics

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Abstract

Development of modern technologies within the philosophy Industry 4.0 resp. Industry 5.0 brings new opportunities in terms of logistics management and implementation in practice as well as stand-alone autonomous systems. Related to this is the problem of identifying the possibility of using autonomous systems for the needs of building an autonomous logistical system. The aim of this paper is to point out the already existing autonomous systems in logistics practice and, finally, to find a suitable and, at the same time, functional physical model for the purpose of research and subsequent use. Therefore, the paper mainly focuses on current trends, functionality, and utilization of autonomous systems in practice.

Keywords: industry 4.0, industry 5.0, smart logistics, industrial logistics, autonomous system

JEL Classification: O14, O32, O33

1. Introduction

The development of modern technologies under the name Industry 4.0 or Industry 5.0 brings new possibilities in terms of management and implementation of logistics in practice as well as independent autonomous systems. Related to this is the problem of identifying the possibility of using autonomous systems for the needs of building a logistical autonomous system. The article focuses on current trends, functionality, and use of autonomous systems in practice.

2. Current trends in the field of autonomous systems

The main prerequisite for the functioning of intelligent transport systems is a fully functional Internet anywhere on the roads. In any case, Slovakia still has gaps in this, but coverage is still improving. For smart cars to be completely independent, they need high-speed internet so that they can exchange all the necessary data with the surrounding ecosystem. It is thus necessary to cover the mobile telecommunications network up to the 5G level. Autonomous vehicles are expected to bring, among other things, a dramatic drop in accidents. Every year, more than one million two hundred thousand people die in car accidents worldwide. In Europe alone, more than two million accidents occur every year. And driverless cars should reduce these numbers dramatically. Thanks to intelligent transport systems, better use of roads as well as parking spaces is also expected. For several years now, residents of larger cities have been observing a deterioration in the quality of travel in individual car transport. Daily congestion in some areas is even affected by urban parking. It is already statistically proven that in some cities one has even been looking for one parking space for several tens of minutes (Veda na dosah, 2010).

There are 3 ways:

The first way is to be changing the traffic habits of the population, which is a very long process, perhaps in decades. The second way is to build transport infrastructure, but we know that our space cannot be inflated indefinitely. For example, playgrounds, many playgrounds are already occupied by cars. The third way, which is probably the shortest and can be addressed today, is through intelligent transport systems. The focus is therefore on monitoring traffic-controlled intersections, which will help traffic engineers cope with increasingly difficult situations (Veda na dosah, 2010).

2.1 City transport

It is a single-decker electric bus that is 12 meters long and has a capacity of almost 80 people. It is also equipped with many sensors and navigation controls controlled by a comprehensive artificial intelligence (AI) system. The company also declares that it is equipped with state-of-the-art cyber security measures to prevent unwanted cyber-attacks. The Volvo bus is the first of two models to undergo preliminary rounds of rigorous testing at the Centre for Excellence and Testing and Research of Autonomous Vehicles at NTU (CETRAN), where there is an artificial track along with all elements of the city – there are traffic lights, pedestrian crossings, stops or even a simulation of bad weather.

Figure 1: Autonomous bus

Source: Mogg, 2019 (https://www.digitaltrends.com/cars/watch-volvo-test-its-full-size-driverless-bus-in-singapore/)

2.2 Rail transport

The Chinese government named the line "The world's first intelligent high-speed rail". Its construction lasted four years and has 10 stops. Trains will automatically stop at each station and run according to a precise timetable, with the speed between stations being monitored by sensors. The train will reportedly be equipped with state-of-the-art features, including seats with a 5G touch screen, intelligent lighting, face recognition and thousands of sensors that will monitor safety in real time. The cabins will have plenty of storage space for sports equipment, including flexible seats for wheelchair passengers. China, of course, is no newcomer to high-speed trains. According to various sources, the country's extensive high-speed rail network covers more than 32,000 kilometres. The country is also home to the fastest Shanghai Maglev commercial train whose top speed is 431 km/h. Only recently was a prototype of a new high-speed Maglev train with a maximum speed of up to 600 km/h introduced (Wilson, 2020).

Figure 2: Autonomous train

Source: Wilson, 2020 (https://www.theguardian.com/travel/2020/jan/09/worlds-fastest-driverless-automated-bullet-train-launches-beijing-china-olympics)

2.3 Freight transport

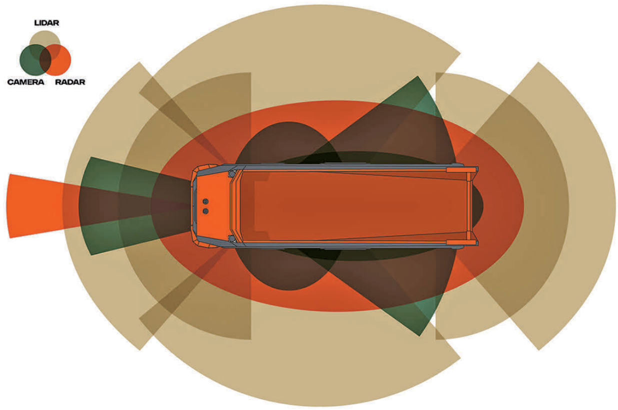
Using cameras and radar and lidar sensors, Scania engineers have taken significant steps towards fully autonomous vehicles. The challenge was to replace the human eye and the ability of the human brain to make decisions based on what the eye sees. Autonomous vehicles often relied on camera and radar data. Radar sensors are reliable, but their resolution does not allow the identification of pedestrians and small objects located at a greater distance. The camera offers a sufficient level of detail and a good overview in two-dimensional format, but it requires extensive software to convert a 2D image of the environment to 3D format. In general, software is more important than autonomous vehicles. An additional sensor is required to ensure safe autonomous driving. It is called lidar (Light Detection and Ranging), which is short for light detection and distance measurement. "We need the functions of the sensors to overlap, so that the sensor can serve as a backup and, if necessary, take over the functions of another sensor," says Fredrich Claezon, systems architect for autonomous vehicles. "What happens when a camera and radar design conflicting information? Which of these sensors should we trust? With LIDAR we can get a better basis for a decision. Scania's first, fully autonomous, self-propelled concept truck, Scania AXL, is equipped with cameras, radar, LIDAR and GPS receiver. The system is designed to meet the needs of mining operations.

"The system is not yet intelligent enough to be used on the road, but it is certainly intelligent enough to be operated in mines," said Magnus Granström, a development engineer in the autonomous systems development department. The human eye cannot be easily replaced, but sensors can provide a relatively good view of the surroundings. "In this case, we see what we need to see," Granström explains. "Mining is quite simple and predictable. If you are driving in a more dynamic and less predictable environment, more aspects need to be considered. It has been difficult to decide how complex the system should be. This involves finding a balance between developing a more general system for many applications and "The Scania AXL would most likely not be suitable for city driving, but it is intelligent enough given the expected environment and planned tasks," says Granström (Tamayo, 2019).

Figure 3: SCANIA autonomous truck

Source: Tamayo, 2019 (https://www.scania.com/content/dam/scanianoe/market/sk/experience-scania/pictures/press-releases/2019/10/nakladne-vozidlo-bez-kabiny---predstavujeme-koncept-scania-axl/Ako-senzory-v-koncepte-Scania-AXL-nahradzaju-ludske-oko_SK.pdf)

Figure 4: The principle of operation of sensors



Source: Tamayo, 2019 (https://www.scania.com/content/dam/scanianoe/market/sk/experience-scania/pictures/press-releases/2019/10/nakladne-vozidlo-bez-kabiny---predstavujeme-koncept-scania-axl/Ako-senzory-v-koncepte-Scania-AXL-nahradzaju-ludske-oko_SK.pdf)

2.4 Ship transport

The prototype of the autonomous ferry was developed by a team from the Norwegian University of Science and Technology. In the full version, the ferry called "Autoferry" will be able to carry at least 12 passengers across the canal, along with their bicycles or prams. If there is no autonomous ferry on the given side of the canal when arriving at the pier, passengers will be able to call it at the touch of a button. During passenger pick-up and unloading, the ferry automatically charges the battery using chargers installed in docking stations.

As soon as the ferry picks them up, it will start navigating independently towards the opposite side of the canal. It uses the on-board GNSS (Global Navigation Satellite System) for orientation and is assisted by four integrated sensors: radar unit, infrared camera, optical camera and LiDAR laser light detection and tracking technology, which creates a 3D map of the surroundings and allows the system to avoid other vessels. Additional sensors are located on the shores and help with wireless data transmission to the ferry.

The developers hope that the autonomous electric ferry Autoferry will get into full operation sometime within the next year. Meanwhile, the remote-controlled prototype is being tested at half scale. He will cover 100 meters from one shore to another in one minute. If pedestrians decide to cross the canal over the nearest bridge, it will take 10 to 15 minutes. The construction of another bridge would allegedly cost more than the operation of an autonomous electric ferry and, in addition, would disrupt shipping traffic (Mališka, 2018).

Figure 5: Autonomous ship

Source: https://cdn.ttgtmedia.com/rms/computerweekly/Ocean%20Space%20Drone_mobile.jpg

2.5 Road passenger transport – Intelligent vehicle

As a result of increased road safety, there is a growing need for cars with strong safety features. The near future on European and world roads will belong to the cars, which will communicate with each other and, in the event of danger, even take control. IDS and increasingly sophisticated traffic management technologies will soon complement smart cars.

The modern car is designed with special emphasis on ensuring a high level of safety for passengers and other road users (e.g., pedestrians, cyclists). To ensure a high level of vehicle security, they are equipped with systems to support selected driving activities and in some cases can replace the driver, e.g., in the event of an accident, they report the position of the vehicle and thus call for help. Advances in measurement technology and information systems have opened new possibilities for automating the vehicle control process. At present, it is technically possible to build fully automated vehicles, but problems of use stem from technical difficulties that arise during urban traffic testing and current legislation, which does not address the legal responsibility for driving intelligent vehicles that "go without a driver and cause an accident."

Modern vehicles have different types of active and passive safety systems, as well as electronic power steering, which are considered as autonomous systems. Today, vehicles have many sensors that transmit information to the host computer, which is responsible for analysing and deciding on the situation on the road (Kalašová et al., 2022).

One of the systems used in an intelligent vehicle control system is to maintain the distance between vehicles. A novelty is the possibility of using intelligent cruise control ICC (Intelligent Cruise Control). Using radar, infrared radiation and a laser beam, it checks moving objects in the vicinity, as well as the so-called driving moving in front of him. If it finds a collision risk, e.g., the car in front is too close in front of the vehicle, cruise control reduces the driving speed and adapts it to the car in front, after it turns or accelerates the system gradually increases the driving speed to the default value. Adaptive Cruise Control (ACC) – A radar cruise control that is like conventional cruise control in that it maintains a present vehicle speed. However, unlike current cruise control, this new system can automatically adjust the speed to maintain the correct distance between vehicles in the same lane. If the vehicle decelerates or if another object is detected, the system sends a signal to the engine system and the vehicle starts to brake and decelerate. Then, when the road is clear, the system automatically accelerates the vehicle back to the set speed. The measurement of speed and distance between vehicles is performed using a radar sensor located on the front of the vehicle, which works based on the Doppler effect. This improves driving comfort, especially in low visibility (e.g., in fog). To create an autonomous system for vehicles, it is necessary to ensure correct motion detection and maintain a safe distance between other vehicles in motion (Kalašová et al., 2022).

The automatic safety brake is also based on ACC elements, which stop the car without the driver's reaction if it detects an obstacle on the road. This is one of the basic functions of an autonomous vehicle. This feature has been known since 2008 as Volvo City Safety. The system detects blocking vehicles at low speeds (up to 30 km/h) and brakes the car automatically. The principle of operation of City Safety is shown in Figure 1. The system uses radar to detect vehicles and sends a signal to the brakes when shortening between vehicles, which automatically brakes. At present, the system informs the driver of the threat by means of light and sound signals, while the City Safety activation system illuminates a warning light on the instrument panel indicating the operation of the City Safety system.

When looking in the rear-view mirror, the driver does not have to notice the vehicle in front, especially if it is small, because it is in the so-called dead angle. The blind spot monitoring system works based on radar sensors. It was first introduced by BLIS (Blind Spot Information System) by Volvo. The system helps to detect the presence of vehicles in the so-called blind spot (an area around the vehicle which cannot be directly inspected by the driver) and inform the driver of this fact. Cameras installed in the driver's side mirrors, when the vehicle is in the detected zone by activating a red light on the door pillar to this fact the driver. Radar sensors monitor the space on the sides and behind the car. There are usually two and they are located on the sides of the rear bumper. Blind Spot Assist, also known as Side Assist, works depending on the car's philosophy at speeds as low as 30 km / h. The driver warns the approaching vehicle in a blind spot by flashing the orange icon if he still wants to go to the side lane, the icon colour turns red and an acoustic signal sound. In these cases, active systems intervene in the vehicle's braking system to prevent or at least reduce the consequences of a collision.

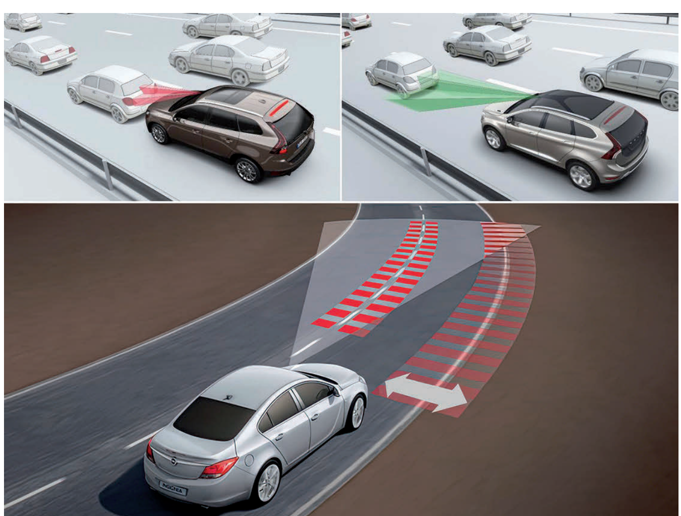
Suitable car systems can also recognize the situation at an intersection. The vehicle is equipped with miniature television cameras, which are located on both sides of the front bumper, which capture the image of the traffic situation in front of the vehicle. The information appears on the on-board computer monitor. The system allows you to control the traffic situation if the driver enters an intersection (Kalašová et al., 2022).

A new solution to facilitate driver parking is the Optical Parking System (OPS). It provides comfort and a perfect overview when parking. On the screen, the on-board driver can monitor the area behind the vehicle and adjust the maneuverer according to the displayed parking lanes, derived from the width of the vehicle. The system uses the image on the display to show the current distance to the obstacle. The OPS system facilitates parking, and the driver can determine exactly when the car is approaching an obstacle.

Parking uses wide-angle digital cameras that can help or completely replace rear-view mirrors in the future. The image from the camera allows easy monitoring of the traffic situation behind the vehicle on the display. The system is activated when reverse gear is engaged. The development of parking support systems is called a parking assistant.

VW has developed a system that allows the car to be parked automatically, without any driver intervention. The system uses ultrasonic sensors to scan the area around the vehicle and evaluate whether there is enough free space to park the vehicle and, if it evaluates positively, it will automatically park the vehicle. During the manoeuvre, the driver operates only the accelerator and brake pedals, the vehicle is always taken over by the parking assistant. The multifunction display and audio signals from the driver's parking sensors provide information on the distances at the front and rear of the vehicle. In conditions of reduced visibility and at night, a system called "night vision" is very useful. Night vision uses infrared light, which the human eye does not perceive and thus does not blind oncoming vehicles. In addition to the usual lights, two infrared headlights illuminate the road and, with the dipped beam on, widening the driver's field of view by a further 150 m. The night visibility system will help identify pedestrians, cyclists, parked vehicles, and other obstacles on the road much earlier. An infrared camera is built into the windshield, which records the image of the road ahead and transmits it to the display. "Night vision" vehicle imaging system (Kalašová et al., 2022).

Figure 6: The principle of operation of intelligent vehicles



Source: http://www.svetdopravy.sk/wp-content/uploads/2015/01/obr.1.jpg

Figure 7: Vehicle display systems

Source: http://www.svetdopravy.sk/wp-content/uploads/2015/01/obr.4.jpg

3. Autonomous systems in industry

Every company needs information to function. Information needs to be shared, communicated, and stored. For them to be treated as well as possible and for the right information to be available at the right time and in the right place, it is necessary to have the appropriate technologies, and all this must be coordinated. All aspects together are called corporate information system. Today, no company can do without the support of an information system to manage its core functions in the areas of personnel, property, tax, finance, warehousing, business agendas, investment activities, and other standard areas of business management. Each information system must respect the specifics of individual sectors, must ensure internal communication, support decision-making processes, and strengthen the competitiveness of companies in the market. The quality of the processes taking place in the company and their efficient organization not only affect the amount of costs, but also affect the volume of sales and together with the amount of profit. That is why it is also necessary for companies to pay attention to the way in which they organize their processes and strive for their continuous improvement. In terms of the amount of information, it is essential that there is enough information at the right time, in the right place, but not excess information. To improve the competitiveness of today's companies, it is no longer enough just to introduce new technologies and investments, but a well-functioning autonomous logistics system is also needed.

3.1 Autonomous mobile robots

The Autonomous Mobile Robots market continues to thrive, with multinational manufacturers throughout the supply chain integrating these flexible robots into their overall internal logistics automation strategies. Autonomous mobile robots are a simple, efficient, and cost-effective way of automation, material handling and internal transport in almost every situation. Businesses of almost any size and in almost every industry are looking at automation to help improve the competitiveness and safety of employees. Manufacturing processes were the early goals of automation, and advances in cost-effective, safe, and easy-to-deploy robots quickly made this type of automation available to small and medium-sized enterprises (SMEs). After seeing a rapid and substantial return on investment from these technologies, business leaders are now trying to automate other uneconomical processes in their organizations. Autonomous Mobile Robots are collaborative and designed to work with people. Being completely safe is a key feature for collaborative mobile robots that run in a dynamic environment and work with humans. If a person encounters an Autonomous Mobile Robots, the safety laser scanning system interprets the obstruction quickly enough to either redirect or stop completely to prevent a collision. They can be part of a fully automated fleet of robots that transport goods around the warehouse or between the production facility and the warehouse. For example, at Flex's plant in Austria, two ATRs move materials along a 600-meter section from the warehouse to the product area without interruption, freeing employees from monotonous transportation tasks, and at Magna-power, based in New Jersey, two ATRs have released the equivalent of three full-time employees. from the re-transport of low-value components and assemblies so that workers can focus their skills on higher-value activities. The main goal is the transport of material, where there are many opportunities to significantly optimize processes and workflows with Autonomous Mobile Robots. There are several types of autonomous mobile robots. Their parameters depend on their type of use, the size of the load, but also their speed and ability to cooperate with humans. Some types are designed to transport lighter loads over short or longer distances. Most of these robots are designed to transport heavier loads on pallets or separately. In the following pictures you can see some types of these autonomous mobile robots (Mobile Industrial Robots, 2022).

Figure 8: Autonomous mobile robots

Source: https://www.mobile-industrial-robots.com/media/1817439/mir600-1.png?width=950&mode=crop

3.2 Automated guided vehicle

The AGV is a mobile robot, an automatically controlled transport device that can move according to signs or wires placed in the floor or uses a laser to track optical symbols. These are devices that do not require human control. AGVs are currently on the rise as they make material handling easier and, with their independence, increase efficiency and reduce human resources in logistics. They also help automate production facilities. Their use is most often in companies with a high volume of production, where large amounts of material are handled in production halls or warehouses (for example in factories in the automotive industry). The load is usually carried in trolleys towed in a sling that can be attached autonomously. Some AGVs use a forklift to store the object in height. The AGV must be able to decide when choosing a route. This is done using various methods: according to the method of frequency selection (driver guidance), the method of path selection ("wireless" navigation), using magnetic strips on the floor (Emans, 2020).

Figure 9: AGV in Industry

Source: https://lh3.googleusercontent.com/proxy/kLimFnu3UY58zKwqGUQJSliODe9t6rrzanJzwbvHRz7QfsT40bCUYMh235jpg.

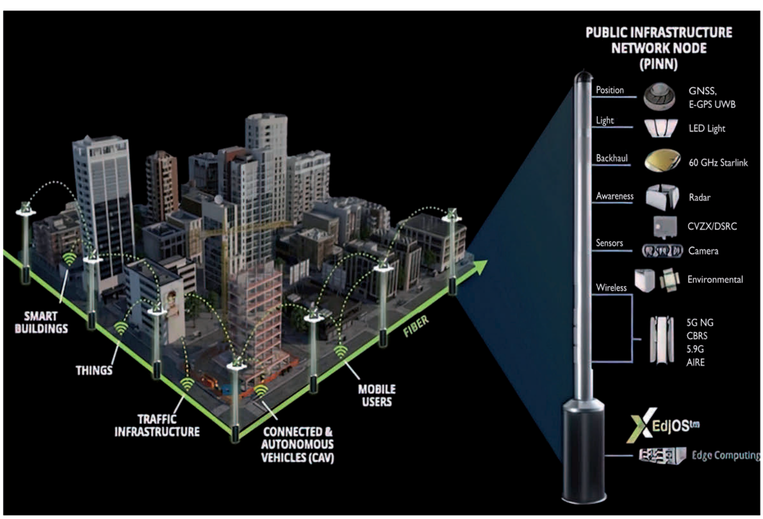
4. The future of intelligent vehicles

The basic functions of intelligent transport systems, which are applicable in all modes of transport, include traffic management and regulation, intelligent vehicle functions, electronic charges, emergency management, public transport management, travel planning, traffic information, fleet management and transport logistics costs, thereby increasing road safety. An important element of this system is intelligent vehicles, which are intended to replace driver activity. State-of-the-art intelligent vehicles can communicate with each other to exchange information about the current traffic situation. The Global Navigation Satellite System (GNSS) is a very important technology in smart vehicle design. It provides accurate and fast location search almost anywhere in the world. One of the most important goals of Intelligent Transport Systems (ITS) is to prevent the loss of accurate vehicle location and control due to a decrease in GPS signal quality. In FIG. 6 is an integrated GNSS and IMU (Interial Measurement Unit) antenna on the roof of a vehicle, used by a research team in Spain. The integration of both devices allows to solve the problem of unavailability of GPS data in the urban environment and improve accuracy. The basic functions of telematics systems, applicable in all modes of transport, include traffic management and control, intelligent vehicle functions, electronic charges, emergency management, public transport management, travel planning, traffic information provision, fleet management and freight logistics.

The GNSS system is also used in the so-called cooperative systems that are based on communication, not only between the vehicles themselves but also between vehicles and infrastructure. These systems are another major challenge for ITS and promise great benefits in terms of transport system efficiency and road safety. The benefits include increased road network capacity, reduced congestion and pollution, shorter driving times, improved road safety for all road users, lower vehicle operating costs and better organization and management of the road network.

In addition to the intelligent vehicle, we must also build intelligent infrastructure. Many larger and medium-sized cities are equipped with progressive adaptive computer traffic management and information systems. More and more European motorway networks are equipped with traffic management, accident detection and travel information, which increases safety and user comfort. The basis for effective traffic management is the availability of real-time traffic information. Traffic data are recorded by detectors installed in critical sections of the road network. Video sensors are increasingly being installed and their data being analysed by image recognition systems. Further advances in mobile communications, traffic management, information and communication technologies will make it possible to avoid traffic disruptions and offer new innovative ways of traffic management. The first vehicles with the Car-to-Car system may appear on the road soon (Svet dopravy, 2021).

Figure 10: Intelligent infrastructure



Source: https://scwcontent.affino.com/AcuCustom/Sitename/DAM/026/PINN_smart_cities_ autonomy_institute_PR_rt.jpg

5. Conclusion

At a time when there is great pressure to improve the economy of the company's own funds, investing in autonomous logistics systems seems to be the optimal solution for the company. It is very important to manage companies with quality and appropriate systems. Deficiencies in corporate systems can cause production downtime, which can lead to penalties for not delivering products, even to the loss of the customer. The aim of this article was to research the currently available possibilities of using autonomous systems in various areas of logistics. These systems make it possible to shorten and streamline the supply, production, transport, and transportation process.

In the article we have described current trends in the field of autonomous systems that are used in practice. Our goal in university is research to better understand the functionality of these autonomous systems and then use the results of the research for the benefit of the faculty and the teaching process.

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Diversity and Inclusion Practices impact on Firm Sustainability: Evidence from the Czech Automotive Sector

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Abstract

The paper investigates the process of development and implementation of diversity and inclusion practices as a part firm strategy. The study covers sample of small and middle-sized automotive firms, where diversity and inclusion practices have been implemented in relation to the firm sustainability. The paper methodology is based on theoretical models of diversity management and firm sustainability in the automotive sector. Paper's results demonstrate that low number of firms in the Czech Republic in the automotive sector have been rolling out any diversity and inclusion measures but at the same time majority of the selected firms have been considering development and implementation of human resource management practices in the area of diversity and inclusion as vital part of attracting more investors and aligning with the global sustainable goals of United Nations. Moreover, the paper brings evidence that the firms are following the global and regional trends on diversity and inclusion in the automotive sector in the Czech Republic as an important step for sustainable strategic development.

Keywords: diversity, inclusion, sustainability, Czech, automotive sector

JEL Classification: O15, L25, M21

1. Introduction

In nowadays business world diversity dimensions are becoming more and more atypical especially personal traits, leadership skills, international experience, identity, exual orientation, political views and other key features for each company. Also, diversity and inclusion measures taken by companies on such mental health, employees' well-being are indirectly or directly affecting the behaviour and the strategic decision-making approaches across executives within the boards (Agnihotri & Bhattacharya, 2020). Thus, the company becomes more aware of the social importance not only for its shareholders, but for its stakeholders including the communities as well. This stems from the fact that in recent years the companies are conducting business but at the same time shifting towards behaving as more sustainable and accountable in front of its shareholders, stakeholders and potential investors as it is inevitable especially during COVID period (Velinov et al., 2020). At the same time, the companies are promoting diversity especially in the upper echelons in order to give examples to their employees and to the respective industries, where they are operating (Huang et al., 2020). Therefore, the need to study explicitly the relationship between TMT diversity and social firm behavior through the Diversity and Inclusion measures is imperial for explaining the phenomena in management and business (Agullera Guerrero-Villegas et al., 2018).

2. Literature Review

From the theoretical point of view gender diversity in corporate boards can influence performance through many channels. Greater gender diversity brings increased heterogeneity in attitudes, beliefs or values, improving the decision-making process. Furthermore, a higher proportion of women in the boards can enhance creativity and critical thinking (Christiansen et al, 2016; Lee and Farh, 2004). Shrader et al. (1997) assume that managerial talent is distributed normally among women and men in the case of greater representation of women in boards and also improves organisational learning and climate. On the other hand, gender diversity could also increase factors, which have negative effect on firm performance. For instance, results of Melsom (2015) indicate a positive relationship between female managers and sickness absence rates or Lee and Farh (2004) suggested existence of lower group cohesion in gender mixed groups. According to Kanter´s critical mass theory (Kanter, 1977) the effect of women representation in boards on corporate performance is mixed and determined by gender composition of controlled group. This theory postulates that, until a certain "critical mass" of women in a group is reached, this group does not benefit from the different abilities and skills that women bring into the group.

Age diversity management across organizations has been discussed widely in the literature review. Majority of studies show that age diversity is negatively connected to firm performance and firm prosperity (Tanikawa et al., 2017). Furthermore, age diversity management has emerged especially throughout COVID era across the firms as they have faced four different generations working in the multinationals (Bengtsson et al., 2020). Also, there is a shift in the upper echelons of the multinational firms and middle-sized firms by having on board top managers, who are either generation Y or Z, which differs from what used to be in the early 2000s. Below are listed three relevant and up-to-dated studies, which cover age diversity management (Paoletti et al., 2020).

According to Resource dependence theory, board members' international experience is one of the key factors for access to information and knowledge of international best practices and contemporary business strategies (Bocquet et al., 2019). Higher proportions of board members with international experience positively influences companies' access to essential resources, such as advice regarding international best practices (Heyden et al., 2015). Companies with internationally experienced board members can better introduce and encourage international business policies including CSR practices. CSR maintains better stakeholder engagement and offers companies a form of competitive advantage over rivals,which leads to reducing the cost of capital, strengthening market position and enhancing profitability (Shahbaz et al., 2020).

Foreign directors can bring their cultural values and perspectives on companies' role in society and stakeholder view of business into communication in boards. Foreign board members are also more focused on shaping visions and more CSR-oriented business (Harjoto et al., 2018). These foreign board members' presence brings new different views, experiences, or access to networks (Beji et al., 2021). Harjoto et al. (2018) published one of the few studies focused on the link between nationality diversity and inclusion practice. They find that board nationality diversity is positively related to diversity practices (Ozbilgin, 2019).

There are few studies focused on the link between board members and their educational level. Beji et al. (2020) found a significant association between CSR overall score and the percentage of highly educated chairperson. Directors with higher educational level are more sensitive to the ethical issues required by some stakeholder and compliance with regulations. A lot of studies have found that more educated managers are more interested in environmental issues (e.g. Zhou et al., 2022).

The results of previous studies indicate that CEOs with shorter tenure are more willing to undertake socially responsible activities such as implementation of various Diversity & Inclusion practices (Yuan et al., 2019). In harmony with revealed arguments by Miller (1991), we present a hypothesis that CEOs having shorter tenure are more likely to report CSR information to reduce pressure from the stakeholders (Khan et al., 2020).

3. Methodology and Data Sample

The paper covers 44 automotive companies from the Czech Republic, which have been selected based on their volume of sales and turnover for year 2021. The data have been collected from companies' websites, online quantitative survey, which took place in the period June-December 2021. Furthermore, we have collected data from Albertina, LinkedIn and consultancy groups reports on Human Resource Management, Diversity, Equity and Inclusion. The availability of Diversity practices was checked through the firms' websites, annual reports and social media activity, which helped the authors emphasize on the data reliability (see Table 1 below).

Table 1: List of Automotive companies- data collection on Diversity, Equity and Inclusion

Firm name	Diversity Practices	Equity and Inclusion Policies
SKODA AUTO	X	X
Hyundai Nosovice	X	X
DENSO	X	X
TPCA Kolin	X	X
Irisbus Iveco	X	X
SOR Libchavy		
TATRA Koprivnice		
Avia and Ashok Leyland Motors	X	
Benteler	X	
Continental	X	X
MAGNA	X	X

KOITO	X	X
MOTORPAL		X
Saint-Gobain	X	X
SungWoo Hitech		
TRW	X	
Faurecia	X	X
Robert Bosch	X	X
Hella Autotechnik	X	X
Kovovyroba Hoffmann	X	
Klein&Blažek	X	
Mann+Hummel	X	X
ZF Plsen	X	X
Hayes Lemmerz Alukola	X	
Ronal	X	X
Mitas	X	
Johnson Controls	X	X
Panasonic Automotive Systems	X	X
Toyoda Gosei	X	X
TI Automotive	X	
Motorpal	X	
Kautex -Textron	X	X
Cooper-Standard Automotive	X	X
Brano Group	X	
Defend	X	
Witte	X	X
EuWe Eugen Wexler	X	
ITG Automotive Safety	X	X
ABB	X	
FILSON	X	
TVM		
Furukawa		
Mitsubishi Electric	X	X

Source: own elaboration

The research model is based on studies by Ozbilgin, 2016 on global and regional diversity management practices, which suggests that local SMEs rather adapt their diversity and inclusion practices to the local standards but still they implement some features from the global diversity management approach in order to stay competitive and attractive to the stakeholders.

4. Results and Discussion

After rolling out of two rounds of online questionnaires among the SMEs in automotive sector in Czechia, paper results reveal that majority of respondents are rather conservative and careful in providing answers on diversity and inclusion practices, which have been implemented across the firms. The tables below show that majority of selected firms have implemented ethical codex, which reflect mainly gender, sex and age dimensions of diversity. Also, the companies are reflecting inclusive HR practices on ethnical background, religion and educational background (see Table 2 and Table 3 below).

Table 2: The top three diversity dimensions, which have been reflected in SMEs' ethical codex

Diversity Dimension	Gender	Age	Ethnical background
% out of 100	83.33		
% out of 100		66.67	
% out of 100			50.00

n=44

Source: own elaboration

Table 3: Top three Diversity and Inclusion practices across the selected automotive firms

Diversity Dimension	Percentage out of 100		
Women	83.33		
LGBTIQ		33.33	
Minority groups			33.33

n=44

Source: own elaboration

Majority of the selected automotive firms are focusing on counseling and mentoring its employees, as they offer consultations on social aspects, social policies supporting minority groups. Furthermore, the firms are still lagging behind in comparison to their counterparts from the Western countries on implementation of adequate diversity and inclusion practices such as part-time jobs, veterans support, religious and ethnical resource groups and practices on equity.

5. Conclusion

Paper results show that the majority firms from the data sample rather consider implementing diversity and inclusion practices but still they have not done so due to different priorities in their business strategies. Furthermore, the study shows that the importance of the diversity, equity and inclusion for the SMEs in automotive sector in Czechia has already picked up higher speed, which makes different stakeholders to pay higher attention to diversity and to engage firms' top management in adapting more and more best practices on equity and inclusion in order to make the companies more attractive for the potential investors and to comply with the global trends and standards on diversity and inclusion.

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Selected issues of the energetics of personal electric vehicles

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Abstract

The paper describes selected issues of electric vehicles (EV) for personal use, from point of view of energetics. Data for the article were collected in real traffic and was used several types of EV. Text is focused to describe the total power consumption of electric energy of EV and its efficiency, on the selected typical types of routes. The influence of the different types of charging (AC/DC) and their efficiency is also covered. The paper also describes the topic of non-traction power consumption (air conditioner, temperature management of the traction battery, 12 V onboard power supply network), which can significantly affect the maximum operating range of EV (typically mainly on routes with low traffic speed - e.g. in town). Data from the summer and winter seasons are compared. In some cases, the comparison between EV and vehicle with a convention combustion engine is done.

Keywords: battery, charging, electric vehicle, range, power, consumption

JEL Classification: L920, L940, L990

1. Introduction

Personal electromobility within the EU is no longer a mere theory, but rather a reality. This is substantiated by EU statistics, which show year-to-year increase of sales of purely battery-based electric vehicles (BEV) from 3% in 2019 to 10.5% in 2020 (ACEA [online], 2021) of the total amount of sold personal vehicles. In Czech Republic, there has been an increase form 0.3% in 2019 to 1.61% in 2020 (according to the Traffic Research Centre [online], 2021). This trend has forced us to stop and think about how efficient the BEV will be not just in precisely defined testing cycles (De Gennaro, 2015), but also what kind of operational values they reach in real conditions and traffic in the Central Europe, especially the Czech Republic.

It has been known for a long time that the electrical motor is an indisputable advantage of the BEV. These machines feature high reliability and primarily efficiency, which exceeds 80% (Hayes, 2017), (Albatayneh, 2020). In comparison, conventional, gasoline, internal combustion engine (ICE) is known for its low average efficiency of about 20% (Hayes, 2017). Despite the efficiency of the BEV propulsion being significantly higher, however, the energy density of the battery storage is many times lower compared to the energy density of a gasoline tank in a combustion engine car. Consequently, while

BEV are much less energy-demanding to operate, they have a more limited operational range than ICE cars.

Due to the high efficiency of the electrical propulsion, it also cannot be relied upon to heat the passenger space up, using the heat from its losses. This leads to further energy consumption demands and therefore reduced range. According to the available data (Vražić, 2014), (De Gennaro, 2015), (Fiori, 2016), (GEOTAB [online], 2020) it is, in some cases of BEV, necessary to expect up to 50% of the energy stored in the traction battery to be used to power auxiliary devices – primarily to air-condition the vehicle.

This study presents the measurement results of power consumption and efficiency values of BEV from real operation, during the summer of 2021 and winter of 2021/2022, and provides a summary of what kind of energy consumption and its distribution among the critical parts of the vehicle can be expected from modern BEV. The measurement from the summer season was repeated in the winter using the same methods to determine the practical influence of ambient temperature. The paper also includes how various types of vehicle charging affect the end-usage of BEV.

The goal of the text is not to bring new theoretical findings regarding the BEV operation, but rather thoroughly present the experience with using BEV in the Czech conditions. The acquired data may be used as a reference for validation of models in terms of estimated BEV range (Wang, JQ, 2018), (Wang, JB, 2017), (Fiori, 2016).

2. Real Power Consumption of a BEV in the Czech conditions

One of the biggest problems, related purely to electrical vehicles, is their operation range. In order to determine the values achievable by the selected BEV, it is first necessary to find out how much energy is actually consumed when driving.

The overall BEV consumption can be subdivided in to 4 basic segments:

- Traction, i.e. the energy required by the vehicle's propulsion system
- Air conditioning (HVAC), i.e. the energy required to heat or cool the passenger space
- 12 V system, i.e. the energy consumed by control units and related on-board technology of the vehicle
- Traction battery management, i.e. the energy required for the heating or cooling of the traction battery

It is obvious that the consumption values described above will not be constant and their magnitude and overall distribution of the consumption will depend on the operational mode of the electric car. This mode is determined primarily by the profile of the driven route, driving speed, ambient temperature and usage of recuperation. To determine the needs of BEV, the test routes that are typical for Czech conditions were selected. Several test trips were driven for each route type, confirming the repeatability of the measurements. All of the trips had their start and end at the same spot. A/C was on during summer trips, while heating was on during winter trips. Electrical heating of seats and the steering wheel was not used.

The values below are derived from the combination of speed, position, altitude above sea level (measured using external GPS module), also values copied from the car's infotainment system (energy consumption distribution, ambient temperature), and also data reading from its OBD diagnostic plug (especially energy taken from the traction battery and put into the battery, total energy consumption).

As a reference vehicle, were used the 2020 Hyundai Kona Electric with a 64 kWh traction battery and maximum motor power of 150 kW. The vehicle is equipped with a heat pump. About 3 200 km was driven with the vehicle during the summer and 2 500 km during the winter season.

The operation ranges specified in the tables of this paper represent range estimates calculated from the average energy consumption and battery capacity usage specified in Table 5.

2.1 BEV Consumption on highways

The data come from 8 trips driven on a selected 78 km section of the D11 highway. The maximum altitude profile difference is 79 m, although the start and destination points were always the same. The goal was to drive on the highway at the maximum allowed speed (130 kph); the lower resulting average speed is primarily due to including the time it took start and stop the measurement recording before beginning the trip and after finishing it, entering the highway, as well as the traffic on the highway.

In addition to speed, the high-power consumption of the BEV here is also affected by a low percentage of recuperated energy. This is caused by only a minimal necessity to brake in the highway traffic.

Table 1: BEV Consumption on highways (Average from all Test Trips)

		Summer operation		Winter operation	
Total BEV consumption	[kWh/100 km]	20.25		21.7	
Theoretical BEV range	[km]	317.5		295.1	
Average BEV driving speed	[kph]	110.0		114.5	
Ambient temperature	[°C]	29.9		2.5	
HVAC settings	[°C]	22.0		22.0	
Partial BEV consumption values		[kWh/100 km]	[%]	[kWh/100 km]	[%]
Traction consumption		19.18	94.8	20.43	94.0
HVAC consumption		0.56	2.8	0.87	4.0
12 V system consumption		0.40	2.0	0.43	2.0
Traction battery management consumption		0.10	0.5	0.00	0.0

Source: Research data

2.2 BEV Consumption on countryside roads (class 1 and 2 roads)

The data come from 5 return trips on a selected route in Eastern Bohemia. The route includes 18 km of high-speed roads (110 kph), 5 km of driving through a city using a ring road, 14 km of class 1 roads and 30 km of class 2 roads. The goal was to drive at a maximum allowed speed throughout the entire trip. The incline degree of the entire route is 506 m.

Table 2: BEV Consumption on countryside roads (Average from all Test Trips)

		Summer operation		Winter operation	
Total BEV consumption	[kWh/100 km]	12.45		16.7	
Theoretical BEV range	[km]	547.0		406.1	
Average BEV driving speed	[kph]	49.2		52.0	
Ambient temperature	[°C]	23.5		0.8	
HVAC settings	[°C]	22.0		22.0	
Partial BEV consumption values		[kWh/100 km]	[%]	[kWh/100 km]	[%]
Traction consumption		10.92	87.7	13.39	82.6
HVAC consumption		0.75	6.0	1.92	11.9
12 V system consumption		0.79	6.3	0.89	5.5
Traction battery management consumption		0.00	0.0	0.00	0.0

Source: Research data

2.3 BEV Consumption in urban conditions

The data come from 11 trips (11 x 86 km) in the city of Pardubice driven during business days. Pardubice is located on flat land. The route was copying the route of a number 7 trolleybus, including morning and evening peaks. Due to traffic circumstances, the vehicle spent 30 % of the time in traffic jams. That's why the data records show an obviously increased share of HVAC and 12 V system consumption.

Table 3: BEV Consumption in urban conditions (average from all test trips)

		Summer operation	Winter operation
Total BEV consumption	[kWh/100 km]	11.61	14.1
Theoretical BEV range	[km]	551.2	454.0
Average BEV driving speed	[kph]	22.9	31.4
Ambient temperature	[°C]	26.4	3.2
HVAC settings	[°C]	22.0	22.0

Partial BEV consumption values		[kWh/100 km]	[%]	[kWh/100 km]	[%]
Traction consumption		7.78	67.0	9.47	67.1
HVAC consumption		1.92	16.5	2.96	21.0
12 V system consumption		1.92	16.5	1.68	11.9
Traction battery management consumption		0.00	0.0	0.00	0.0

Source: Research data

2.4 BEV Consumption in mountains

The measurement was conducted in the mountain range of Orlické hory, by repeatedly driving over the peak (990 m above sea level) back and forth, with 345 m of incline over a distance of 5 km (average incline of about 7%). In total, 21 trips by 22 km each. The overall relatively low summer consumption is primarily due to energy recuperation created when braking downhill and optimal ambient temperature (about 22.4 °C), during which the A/C input power consumption is minimal.

The extreme difference between the summer and winter operation can be attributed to three factors: increased driving resistance (continuous layer of snow on the road), significantly decreased share of energy recuperated back into the battery, due to the relatively high power consumption of the heating and significantly lower average speed for the winter trips. The operation range is about 43% lower during winter than during summer. For comparison, an ICE (gasoline) equipped vehicle Opel Astra J (see chapter 4 for the specification of this vehicle) has its range only decreased by 17% in the winter season.

Table 4: BEV Consumption in mountains (average from all test trips)

		Summer operation		Winter operation	
Total BEV consumption	[kWh/100 km]	13.1		23.0	
Theoretical BEV range	[km]	487.9		278.4	
Average BEV driving speed	[kph]	43.7		30.4	
Ambient temperature	[°C]	22.4		-2.8	
HVAC settings	[°C]	22.0		22.0	
Partial BEV consumption values		[kWh/100 km]	[%]	[kWh/100 km]	[%]
Traction consumption		11.88	90.5	17.93	78.0
HVAC consumption		0.46	3.5	3.56	15.5
12 V system consumption		0.79	6.0	1.49	6.5
Traction battery management consumption		0.00	0.0	0.00	0.0

Source: Research data

3. Real Consumption of other electrical vehicles

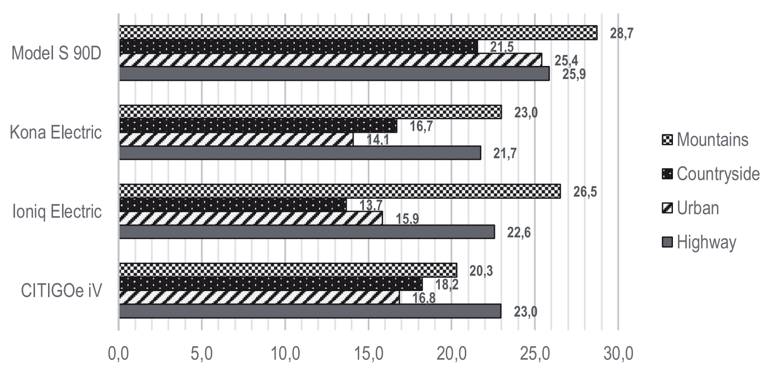
The results in chapter 2 are only applicable to BEV Hyundai Kona 64 kWh. Is appropriate to verify what results can be achieved by some other BEV types. The measurement was conducted during winter, summer data are not available for all of the vehicles involved. The routes and testing conditions were identical to those in chapter 2. The data were gathered from 4 electrical cars that can be encountered commonly in the Czech Republic. Tesla Model S and Škoda CITIGOe iV are not fitted with a heat pump, but rather an electrical resistance (PTC) heater. Both Hyundai vehicles are fitted with a heat pump.

Table 5: Evaluated BEV types

Manufacturer	Type	Year of production	Utilizable traction battery capacity*	Motor power*	Mass***
			[kWh]	[kW]	[kg]
Škoda	CITIGOe iV	2020	32.3	61	1 180
Hyundai	Ioniq Electric	2017	28	88	1 480
Hyundai	Kona Electric	2020	64	150	1 720
Tesla	Model S 90D	2016	81.8**	386	2 210

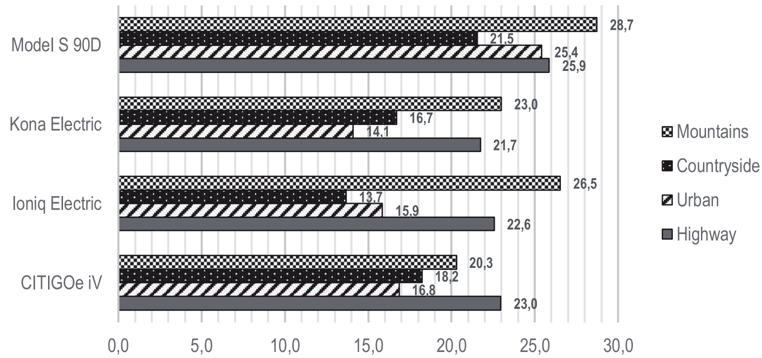
Source: * *Manufacturer's official specification*
** *The manufacturer has not specified the utilizable capacity, data taken from (Electrek, 2016)*
*** *Research data*

Chart 1: Average BEV energy consumption, depending on route type [kWh/100 km]



Source: Research data

Chart 2: Average BEV maximum operation range, depending on route type [km]

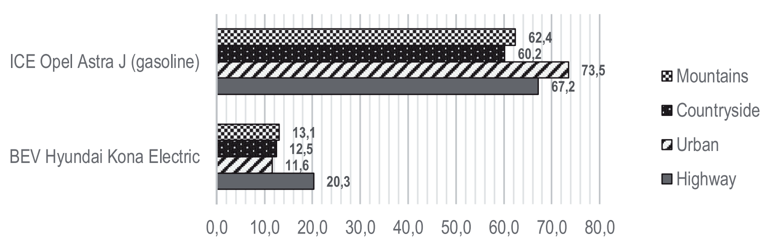


Source: Research data

4. Comparison of BEV and ICE energy consumption

During the study, a conventional internal combustion engine (ICE) car was also driven alongside the battery electric vehicle (BEV). That made for a good opportunity to compare the energy consumption of the aforementioned BEV (Hyundai Kona) and the ICE Opel Astra J (88 kW) equipped with 1.4l turbocharged gasoline engine. The calculations consider 1 litre of gasoline to be equivalent to 8.9 kWh of energy. Data for the summer season are compared.

Chart 3: Comparison of BEV and ICE energy consumption values, depending on route type [kWh/100 km]



Source: Research data

5. BEV charging

There is another issue that is frequently brought up as well as essential for the BEV operation, which is the traction battery charging. The current legislation (IEC 61851) recognizes four charging modes (mode 1 to 4), three of which use alternated current (AC) and the fourth one uses direct current (DC).

5.1 AC charging mode

The AC modes feature low purchase costs of the charging infrastructure (compared to the DC mode), but their charging power is severely limited. That means they are only really suitable for charging stations in family houses or residential garages, i.e. at places where the vehicle can stay for an extended period of time to recharge.

It is apparent from the name that the charging station is supplying the car with alternated current in this case. Since battery cells are in their nature based on direct current, it is necessary to rectify the alternated current coming from the charging station. This is what the BEV onboard charger (OBC) is meant for. With the AC charging modes, it is necessary to include the losses in the OBC itself as well as possible losses from reactive energy.

The table below summarizes the data measured on Hyundai Kona Electric 2020 (64 kWh) with installed OBC of 10.5 kW (3x16 A / 400 V). The data come from a total of 17 charging cycles, which proved a very good repeatability. The vehicle was charged from a wall-box, always to 100% state of charge, at room temperature. The consumed energy was measured using an external energy meter with an accuracy class of 1%.

Measured data were used to evaluate the charging efficiency and the extent to which the BEV is capable to take the available power from the charging station, i.e. level of utilization of this power.

Table 6: Alternate current charging (average from all charging cycles)

BEV charging efficiency (includes losses in the OBC and the battery)	[%]	90.5
Average input power (into OBC)	[kW]	10.0
Rated voltage at the charging station inlet	[V]	3 x 400 V / 50 Hz
Actual phase current supply (into OBC)	[A]	14.7
Utilization of available charging power by the vehicle	[%]	91.8
Average charging power factor	[-]	0.99
Maximum charging completion estimate deviation	[min.]	-21 and +21
Minimum charging completion estimate deviation	[min.]	-2 a +3

Source: Research data

5.2 DC charging mode (DC mode)

The DC mode has relatively higher purchase costs for the charging infrastructure; however, this factor is made up for by the capability of charging with powers that are many times higher (compared to AC modes). These chargers are frequently encountered at malls, public parking lots and highways, where it is necessary to maximally reduce the charging time.

The power of DC charging depends strongly on the BEV's current traction battery temperature and its state of charge (SOC); it also changes over the course of the charging.

Table below summarizes the data measured when charging Hyundai Kona 2020 (64 kWh). These are data from three consecutive charging cycles, where each of the cycles was preceded by driving on a highway for 40 minutes. Passenger space heating was off during the charging.

The charging was done using a DC charging station with a max. output power of 50 kW, which is the predominant type in the Czech Republic.

Table 7: Direct current recharging (average from all charging cycles)

Charging cycle no.		1	2	3
Ambient temperature	[°C]	0.5	2.0	3.0
Initial battery temperature	[°C]	15	22	27
Battery temperature upon charging completion	[°C]	22	28	30
Maximum charging power when charging	[kW]	50.7	50.6	51.7
Minimum charging power when charging	[kW]	24	24	24
Average charging power	[kW]	35	39	43
Utilization of available charging power by the vehicle	[%]	70	79	85
Initial SOC of traction battery	[%]	53.5	55	55.5
SOC of traction battery upon charging completion	[%]	80.0	79.6	79.6
Energy charged (from the screen of the charging station)	[kWh]	22.2	20.7	19.8
Energy consumed by the trip (data from the OBD diag. plug)	[kWh]	17.9	16.9	16.5
Charging efficiency	[%]	80.6	81.6	83.3
Charging time	[hh:mm]	00:38	00:31	00:27

Source: Research data

The charging efficiency is calculated as a ratio of the energy consumed in the previous trip to the energy taken from the charging point during the subsequent charging.

The measurement data show that battery temperature affects the charging time (38 versus 27 minutes) and charging efficiency (80 to 83 %). We can see that the efficiency of DC charging compared to AC charging, which is done at lower rate, is significantly worse (about 81 % for DC compared to the 90 % of AC charging).

6. Conclusion

From the standpoint of electrical energy consumption, the measurement has shown that highway sections are the most energy-demanding route types in the Czech conditions. This is primarily due to the highest driving speed.

On the other hand, the consumption of energy of BEV, compared to summer (exterior temperature 22 to 30 °C), increase during winter (exterior temperature about 0 °C), and the most significant changes are observed in the hill/mountain-like routes.

The higher energy consumption in winter is due to the higher energy demands for heating of the passenger space compared to the cooling (the difference between exterior and interior temperature is higher in the winter than summer), as well as various resistances affecting the vehicle (denser air, more frequent rain or snow, snow-covered road) and the factor of lesser usability of recuperation.

Additionally, the comparison of multiple BEV types shows that even the vehicle with the smallest traction battery in the study (Ioniq Electric 28 kWh) is capable of driving over 170 km in urban conditions and can therefore easily serve the purpose of basic personal transportation in our conditions.

The energy demands of BEVs were also compared to those of ICEs. The comparison has clearly confirmed the presumptions of the energy advantages of electromobility and the disadvantageous efficiency of internal combustion engines. BEV consume 3x to 6x less energy than ICE, depending on the route type. ICEs are the least efficient in urban traffic, for which BEVs are very suitable thanks to low average speed and utilization of recuperation.

In the charging section, it is worth pointing out the high efficiency of the onboard charger during the AC charging of the BEV, which exceeds 90 % (which also matches the observation of Albatayneh, 2020) while the vehicle is capable of use practically all of the available charging power. On the other hand, the DC charging tests have shown that contemporary BEVs are not fully capable of utilizing the maximum recharging power throughout the charging cycle, the charging speed is very dependent on the battery temperature and the DC charging efficiency can be significantly lower.

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Level of Lean Culture and Its Relation to Organizational Life Cycle

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Abstract

Lean Production is widely recognized and accepted in the automotive industry. It concerns the strict integration of humans in the manufacturing process, involvement of all employees in continuous improvement and in waste elimination. The literature emphasizes the importance of the underlying organizational culture as a critical factor for supporting and sustaining lean management implementation. Organizational life cycle plays role in achieved level of lean too. The article seeks to verify whether there is a link between the attributes of lean culture and the stages of life cycle. Therefore, this paper initiates a discussion towards a framework that combines life cycle assessment and appropriate lean culture characteristics to provide the best condition for continuous business improvement. To address this issue, automotive industry was chosen as it is the world's leading advanced manufacturing technology industry producing complex products and is the most advanced industry in using lean.

Keywords: lean culture, lean strategy, organizational life cycle stages, automotive industry

JEL Classification: M 11, M 14, M 15, M 21

1. Introduction

In these pandemic times, it is increasingly important for (not only) private companies to make the right strategic decisions. Individual strategic management activities undoubtedly contribute to the overall prosperity of an organization. In any case, it is advisable to ascertain one's own position within the competition. Since the 1960s, it has been possible to follow the strategic recommendations resulting from the position of a company in its life cycle stage, as each phase has its own specificities and requires different management approaches. At the same time, there is constant pressure on costs reduction, which is greatly facilitated by continuous improvement methods and techniques. According to Zemanová and Slavík (2017), organization can adapt their production according to changing market needs because of implementing lean management. We consider a culture of continuous improvement to be essential in our ability to face competition and to continue to offer our customers quality products at appropriate prices. Concepts such as lean and kaizen are widespread in the manufacturing industries, particularly in the automotive industry, to which these concepts are historically linked. Liker (2004) emphasizes that, lean requires a long-term commitment. A medium-sized company would need about three to five years to start pursuing the lean philosophy. One of the reasons is cultural aspects that plays great role in fulfilling the full potential of lean. If these cultural aspects are missing, companies could not obtain the full benefits of lean manufacturing implementation, and in fact, they are having difficulties sustaining the achieved success. There have been several studies focused on importance of lean culture for lean management. Dorval et al. (2019) identified 678 academic papers with key word "lean" and "culture", but at the same time he mentions that in 86 percent of them, lean culture was only discussed superficially. This article is more specific. The aim of this paper is to open a discussion on the possibility of linking the phases of the enterprise life cycle and lean culture in the automotive industry as the main driver for continuous improvement within manufacturing industries. In the following section, the individual areas are examined in order to discuss the individual points of questionnaire surveys. As a result, within chapter 3, the questionnaire formulation is defined to ensure the stated aim of the paper.

2. Problem Formulation and Methodology

This chapter focuses on the literature review and discussion in the areas of interest of the paper, i.e., organizational life cycle, lean culture, and automotive industry in the Czech Republic. Furthermore, the interconnection of these areas in the scientific literature is discussed.

2.1 Organizational Life Cycle (OLC)

As mentioned in the introduction, the theory of the business life cycle has been in the scientific literature for more than 60 years. Over such a long period of time, a number of models and approaches have been developed with different numbers of phases ranging from three to ten. It is the ten phases that are proposed in the well-known model by Adizes (1979), however, in recent years, authors have been leaning towards a smaller number of phases - three to five (e.g., Dickinson, 2011; Souza et al., 2015; Primc & Čater, 2016; Tam & Grey, 2016).

In general, a company passes through its life from the inception phase, through the growth phase, a maturity phase, to the decline phase, and finally extinction. In the course of the life of an organization, one can also encounter the revival phase, which is very similar in its specifics to the growth phase. In our article, we focus on scientific papers that determine the life stage of a company based on a set of questions.

Souza et al. (2015) propose to use a modified supply chain process management model for their research, which takes into account the maturity of the company. For this purpose, they use a form with 20 questions presented by Lester et al. (2003). The phases are identified as existence, survival, success, renewal, and decline.

Tam and Grey (2016) suggest a set of nine questions where SME managers are self-declaring their firm's life cycle stage. A point system (1, 2, 3) is allocated to answers to relate inception (birth), high growth, or maturity. A total score then identifies a firm to its stage.

Primc and Čater (2016) propose a very brief characterization of each phase in an online cross-sectional survey of Australian listed companies in order to investigate the relationship between firm life cycle phases and environmental proactivity. In doing so, they draw primarily on the characteristics of the phases posited in Miller and Friesen (1983). These stages of OLC are birth, growth, revival, maturity, and decline. The questions are formulated primarily for listed companies, which means that most of them are organizations with strong capital and a solid market position. Concerning the automotive sector, it is quite obvious that these large companies are certainly leaders in their field in terms of continuous improvement methods.

2.2 Lean Culture

Lean set up organizational processes for waste minimization and productivity improvement based upon the use of specialized tools and techniques linked with initiating a culture of continuous improvement. Crucial factor that impacts the success of lean implementation is the adoption of soft practices. (Ulewicz & Kuceba, 2016). This is in line with claim of Liker and Rother (2011) who explain that soft practices are concerned with people and relationship, hard practices relate to the lean techniques and tools and specialy soft practices are critical for achieving maximum efficiency through lean and maintaining productivity in the long run. The organization develops its culture in response to the working environment established by its leadership and management team. The establishment can be guided or not and it can have positive or negative effect on performance. Thanks to an appropriate corporate culture, a company can achieve excellent economic results, while an inappropriate corporate culture can cause barriers to efficient operations (Taherimashhadi & Ribas, 2018).

Organizational culture and the role of leadership are one of the main factors that can impact lean implementation as lean is based on the motivating and supportive approach of management to employees. The role of the leader needs to be highlighted in order to achieve expected results. According to Al-Najem et al. (2012) company cannot operate in lean without a healthy culture, skilled personnel, the buy-in from the top management and a strong leadership.

Al-Najem (2012) propose lean culture assessment model that contains lean critical factors focused on: top management, leadership, empowerment, customer relation, supplier relation, training, departmental relation, teamwork. Companies with successful lean implementation are strong in these areas. Dahlgaard and Dahlgaard-Park (2006) states that the main objective of lean system is to develop pro-active corporate culture, where continuous improvement and people's involvement is essential. Though, empowerment is the precondition for creating the desired culture. Angelis et al. (2011) also states that managers need to take action to enable greater worker commitment.

Ulevitz and Kuceba (2016) mention problems that may limit the potential of lean application. These are lack of commitment of the managers, employees not respecting norm of organization, general lack of knowledge about lean and most importantly limited resources. Sherres-Rathje et al. (2009) add what is the impact of lack of leadership: limited access to resources, communication problems including long-time decision-making process.

Elkhairi et al., (2019) identified 175 research papers that discussed lean implementation. Based on these articles they identified success factors that were divided in 5 groups related to leadership, cultural change, competence and expertise, commitment from top management, education and training, communication. They also identified following barriers to implementing lean management: lack of planning, lack of expertise, lack of commitment from top management, lack of strategic performance, misunderstanding of LM, limited resources, resistance to change.

Adequate lean culture is often described on companies operating in the automotive industry. Companies operating in the automotive industry are known for high level of efficiency and quality and focus on the lowest possible cost as lean is the main philosophy for most of those companies. There is great number of studies focused on lean in automotive industry (Nordin et al., 2010; Nallusamy, S., & Ahamed, A., 2017; Marodin et al., 2016).

2.3 Automotive industry in the Czech Republic

The automotive industry is a logical proxy for lean culture research, given its rich history in continuous improvement development. At the same time, the automotive industry of the Czech Republic represents an important contribution to overall economic development and has a significant impact on the national trade balance; we can expect that selected enterprises will have ample expansion opportunities. Foreign capital plays a decisive role in the Czech automotive industry, most of the members of the Association of the Czech Automotive Industry are held by foreign investors. Domestic suppliers are mostly 3rd tier suppliers, i.e. in a vulnerable position. The Czech automotive sector is currently facing several concurrent challenges.

First of all, "Industry 4.0". The fourth Industrial Revolution is a strategy for being competitive in the 21st century utilizing high-tech technologies, smart automation of traditional manufacturing, and interconnectivity. In this case, the biggest challenge for the automotive industry is the aforementioned automation, smart technologies, and also continuous improvement. As discussed by Mrugalska and Wyrwicka (2017), there is a link between lean Production and Industry 4.0.

Second, there is the "European Green Deal", approved 2020. It is a collection of European Commission policy steps with the goal of achieving the European Union (EU) climate neutral by 2050. These steps need to be taken so that the transition to a more sustainable, greener economy, could be performed. The Green Deal should lead to a reduction in the disparity between the high costs of pollution and the price paid by polluters and users. However, the energy market situation is not ready at the moment to face the risks that may accompany its implementation. At the turn of 2021/2022, energy prices have risen significantly, which has also increased the price of emission allowances. Furthermore, the economy is only just waking up from the turbulence associated with the global pandemic COVID-19. At the same time, coal and nuclear power plants are being curtailed or phased out. And last but not least, Europe is currently facing the impact of the war conflict between Russia and Ukraine from 02/2022, which invalidates all previous forecasts. At the moment, we can only guess how far the economies will be affected by the sanctions imposed on Russia, and how the issue of energy and gas supply restrictions will be resolved.

3. Problem Solution

What stage of the life cycle the Czech automotive companies are situated in? The answer is not straightforward, as it depends on whether the analyzed enterprise is identified as large (more than 250 employees) or small and medium sized (SME). Large companies, for example Hyundai Motor Manufacturing Czech, Ltd., Tatra Trucks, Inc., Iveco Czech Republic, Inc., Toyota Motor Manufacturing Czech Republic, Ltd., and ŠKODA AUTO, Inc., are well established companies with strong capital and solid backgrounds. Based on the quantitative indicators according to Slavíčková and Myšková (2017), we can evaluate these firms as being on the borderline between the growth and maturity phases, as the growth of indicators is not very high, but still shows constant growth. However, this was true for the period prior to the COVID-19 pandemic; from 2020 onwards, financial indicators need to be seen in the broader context of the global crisis with its consequences in the form of supply chain disruptions, and reduced sales, etc.

At the same time, we can state about these large organizations that elements of continuous improvement and lean are part of their corporate culture. Pedersen-Rise and Haddud (2016) confirms that majority of articles about lean focus on large companies with great both financial and personal resources. Except the resources, also the expertise is the reason why large companies apply more lean than small companies (Doolen & Hacker, 2005).

There is only limited number of small and medium-sized companies that adopted lean approach (Achanga et al., 2006). They also state that SMEs have differential characteristics compared to large companies and the touchstones for their success are different. Ulevitz and Kuceba (2016) state that SMEs companies and their management significantly differ from practices used during the stabilized production in large companies. Their research confirms that small and medium-sized businesses have significant challenges in applying the lean approach e.g. that in it is problematic to plan a production and stick with its production schedule, lack of standardization, short-term financial goals, barrier in management and employee relations. Yet, their research showed that there is a great demand for lean philosophy among the SME.

Hence, the question is how the small and medium-sized companies do (in terms of the number of employees) in the automotive industry stand in this area. Here we can expect their capital strength to be less high, their organization to be less hierarchical and less burdened with administration compared to large companies. We anticipate that the issue of continuous improvement will not be a regular part of the corporate culture. Similarly, their life cycle phases are likely to fluctuate between growth, maturity, and decline phases. It is this area that is of interest to the authors for further in-depth investigation.

We offer for discussion the question of whether a relationship can be observed between the phases of the organizational life cycle and the lean corporate culture approach in these SMEs. In order to explore this area, we propose to conduct a questionnaire survey in a group of companies defined as follows:

- number of employees 10-249;
- turnover 2-10 million EUR;

- automotive industry “CZ NACE C29” – manufacturing of motor vehicles, trailers, and semi-trailers;
- financial data history of at least 5 years, i.e. 2017-2021.

For the purpose of a questionnaire survey, we propose a simple questionnaire with 2 main parts to verify the relationships: 1) Identification of the life cycle phase of the company, and 2) Identification of the relationship with the culture of continuous improvement. The statements are based on a systematic literature review about the life cycle phase and typical lean culture characteristics.

The first part contains the following statements, from which the respondent chooses only one that most closely matches the current description of their company (adapted from Primc and Čater, 2016):

- Our company is less than ten years old, has a loose structure, and is run by an owner-manager. Our decision-making is centralized and intuitive, and we occasionally take commercial risks. *This section refers to the birth phase.*
- Our revenues have increased by more than 15% as a result of our cost-cutting programs and inventive strategies. We’ve developed unique capabilities that set us apart from the competition. Our company is organized functionally, with decentralized decision-making and codified procedures. *This section refers to the growth phase.*
- In our company, formalization, and control are the norms. We focus on cost efficiency, while we lack innovation activity. The rate of sales growth is less than 15%, and the level of sales remains stable. Our management focuses on strategy and planning. Risk-averse decision-making is the domain of top management. *This section refers to the revival phase.*
- We’re growing our product line and broadening our markets. Our creativity and invention are aided by the employment of a divisional or matrix structure, with formalized procedures and a decentralized decision-making process. Sales have increased by more than 15%. *This section refers to the maturity phase.*
- Our decision-making and control are centralized and risk-averse. Due to external challenges and a lack of innovation, our profitability has decreased. Our company has a formal and bureaucratic structure. *This section refers to the decline phase.*

In the second part, a 5-point Likert scale is used to express the respondent’s level of agreement with each statement:

- There is two-way communication between employees and management, including feedback.
- Employees are presented with information about the company’s strategy and improvements both verbally and visually.
- Teamwork is required and is a priority when designing and implementing changes.
- Team goals take precedence over individual goals.
- Change is seen as an opportunity, mistakes are tolerated.

- Employees are motivated and involved in the process of designing and implementing change.
- Company values emphasize innovation and creativity.
- Managerial tools and methods are used to manage change.
- All employees participate in continuous improvement and problem-solving.
- Employees proactively face challenges and do not hide from problems.

Prior to conducting the actual survey among the companies in the next phase of the research, the questionnaire should also be discussed among the managers of the selected sector themselves to ensure that the concepts were relevant and that the phrasing and meaning of the concepts were both comprehended.

The output of this part, where 10 managers from the automotive industry were interviewed, was primarily a comment on the impossibility of determining the life cycle phase for very small companies (up to 9 employees), as these companies have no chance to choose only one suitable category with the current simple organization. For this reason, the authors will exclude from the survey the group of small enterprises with less than 10 employees.

4. Conclusion

Priority of every company applying lean is concentrating on customers needs to achieve customer satisfaction.

The authors' questionnaire will be used primarily to examine the relationship between the phase of the life cycle which has the company achieved and the level of culture of continuous improvement. Based on the literature research, the authors assume that it will be companies that have been on the market for at least 3 years that achieve positive results regarding the attributes of lean culture corresponding to the successful implementation of the lean philosophy. In case we confirm high level of lean culture in certain company, we can state that one of the main components of a successful lean implementation has been achieved. We expect that many solutions applied in stable production (typical for large companies) will not be applicable to SMEs and that alternatives will have to be offered to achieve the desired results.

In future research, it is important to find ways for the organization to strengthen lean culture for all employees in every organization even for companies in the early stages of the life cycle.

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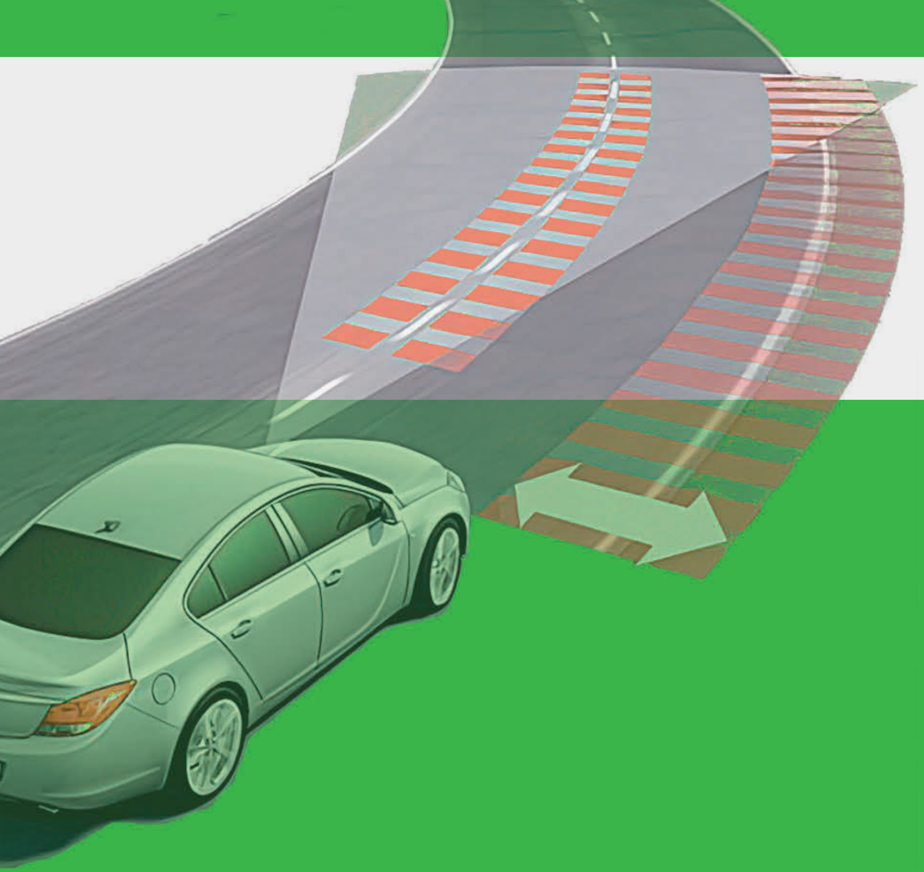

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