TECHNICAL UNIVERSITY OF KOŠICE
Faculty of Mechanical Engineering

Trends and Innovative Approaches in Business Processes 2020

Trendy a inovatívne prístupy v podnikových procesoch 2020

TIABP

Proceedings of the XXIII. International Scientific Conference

The area of the Herlany historical spa
October 12th - 13th, 2020

Conference program committee

Chairman

Dr.h.c. mult. prof. Ing. Jozef Živčák, PhD., MPH

Members / Reviewers

prof. Ing. Peter Trebuňa, PhD.
Dr.h.c. mult. prof. Ing. Jozef Mihok, PhD .
prof. Ing. Milan Gregor, PhD.
prof. Ing. Branislav Mičieta, PhD.
prof. Ing. Martin Krajčovič, PhD.
Dr.h.c. prof. Ing. Michal Cehlár, PhD.
prof. Ing. Vladimír Modrák CSc.
prof. Ing. Radovan Hudák, PhD.
prof. Ing. Gabriel Fedorko, PhD
prof. Ing. Miloš Čambál, CSc.
doc. Ing. Milan Edl, Ph.D.
doc. Ing. Michal Šoltés, PhD.
Dr hab. inż. Sławomir Kłos, prof. UZ
prof. Ing. Radim Lenort, Ph.D.
prof. Ing. Felicita Chromjaková, Ph.D.
prof. Ing Ján Závadský, PhD.
prof. Ing. Petr Besta, Ph.D.
prof. Ing. Rastislav Rajnoha, Ph.D.
prof. Dr. Martin Užik
Dr.h.c. prof. dr hab. inż. Józef Matuszek
doc. Ing. Jaroslava Kádárová, PhD.
doc. Ing. Vladimír Rudy, PhD.
doc. Ing. Miriam Pekarčíková, PhD.
doc. Ing. Michal Puškár, PhD.
doc. Ing. Daniel Kottfer, PhD.
doc. Ing. Peter Frankovský, PhD.
doc. Ing. Martin Straka, PhD.
doc. Ing. Andrea Rosová, PhD.
doc. Ing. Peter Blišťan, PhD.
doc. Ing. Jozef Glova, PhD.
doc. Ing. Ľuboslav Dulina, PhD.
doc. Ing. Patrik Grznar, PhD.
doc. Ing. Marek Laciak, PhD.
doc. Ing. Patrik Flegner, PhD.
doc. RNDr. Jana Pócsová, PhD.
doc. Ing. Michal Balog, CSc.
doc. RNDr. Marianna Trebuňová, PhD.
doc. Ing. Michal Hatala, PhD.
doc. Ing. Andrea Chlpeková, PhD.
doc. Ing. Helena Makyšová, PhD.
doc. Ing. Dagmar Babčanová, PhD.
doc. Ing. Henrieta Hrablik Chovanová, PhD.
doc. Ing. Michal Šimon, Ph.D.
doc. Ing. David Tuček, Ph.D.
doc. Ing. Roman Zámečník, Ph.D.
dr hab. inż. Michał Sąsiadek
dr hab. inż. Piotr Kuryło
doc. Ing. Silvia Ručinská PhD.
Dr.h.c. doc. Ing Milan Fiľo, PhD.
doc. Ing. Jaromír Markovič, PhD.
Ing. Martin Morháč
doc. Ing. Ján Vavro, PhD.
dr hab. inż. Dariusz Plinta, prof. ATH
Ing. Michaela Kočišová, PhD., MBA
Ing. Marcel Behún, PhD.
Ing. Marek Schnitzer, PhD.
Ing. Martin Gašo, PhD.
Ing. Radovan Furmann, PhD.
Ing. Monika Karková, PhD.
Ing. František Koblasa, Ph.D.
Ing. Marek Bureš, Ph.D.

NÁZOV:	**Trends and Innovative Approaches in Business Processes 2020**
EDITORI:	**prof. Ing. Peter Trebuňa, PhD.**
	Ing. Marek Kliment, PhD.
	Ing. Jozef Trojan
	Ing. Marek Mizerák
VYDAVATEĽ:	**Technická univerzita v Košiciach**
ROK:	**2020**
VYDANIE:	**XXIII.**
NÁKLAD:	**50 ks**
ROZSAH:	**152 strán**
ISBN:	**978-80-553-3652-7**

Obsah

PREHĽAD TECHNOLÓGIÍ 3D TLAČE

Jozef TROJAN – Peter TREBUŇA – Marek MIZERÁK – Štefan KRÁL

Abstract: Tento článok je venovaný prehľadu rôznych 3D technológií. Rieši vlastnosti každej technológie a popisuje rôzne výhody jednotlivých technológií 3D tlače, ale aj tvorbu 3D modelov pomocou CAD programov, ktoré majú v dnešnej dobe široké zastúpenie na trhu. Tento článok tiež popisuje význam 3D tlače, ktorá je dnes neoddeliteľnou súčasťou nielen automobilového priemyslu, ale aj lekárskeho priemyslu, kde dokáže vytvárať implantáty nahradzujúce časti ľudského tela. 3D tlač sa používa takmer v každom priemysle, ktorý je pod vplyvom ľudského vedenia. 3D model sa používa hlavne v oblasti architektúry a bytového dizajnu, pri 3D implementácii budúceho modelu. Takto je možné popísať modely vyrobené zo sadrového kompozitu. Je preto skutočnosťou, že 3D tlač uľahčuje a zjednodušuje množstvo zložitých a veľmi nákladných procesov, a prispieva tak k ich ďalšej inovácii.

Keywords: 3D tlač, 3D tlačiareň, technológia

Úvod

Okolo 3D tlačiarní existuje stigma, vďaka ktorej sa neinformovaní ľudia domnievajú, že 3D tlač nie je praktická a jej účelom je vytvárať zbytočné modely a figúrky. To nie je ani zďaleka pravda. Vývoj moderných výrobných procesov je úzko spojený s vynálezmi, ako sú profesionálne stolné 3D tlačiarne, ktoré umožňujú znížiť náklady a čas výroby na minimum. Modernou technológiou 3D tlače je možné vytvoriť objekty využívaním rôznych technologických postupov. Pod 3D tlačou je možné rozumieť aditívnu výrobu, teda proces, počas ktorého sa z elektronických dát vyrába model vo fyzickej podobe postupným vrstvením materiálu. Medzi tieto materiály možno zaradiť sadrový kompozit, rôzne druhy plastov, vosky, živice, kovy, sklo, ale aj keramiku [1].

Najčastejšími spôsobmi pre vytvorenie elektronického modelu sú CAD systémy, 3D skenovanie prostredníctvom 3D skenovacích zariadení. Takisto sem patria aj technické dáta využívané v medicínskych zobrazovacích systémoch. Model, ktorý je vytvorený v počítačovom programe, je potrebné rozdeliť na tenké horizontálne vrstvy a takto upravený model je pripravený na odoslanie ako informácia do 3D tlačiarne.

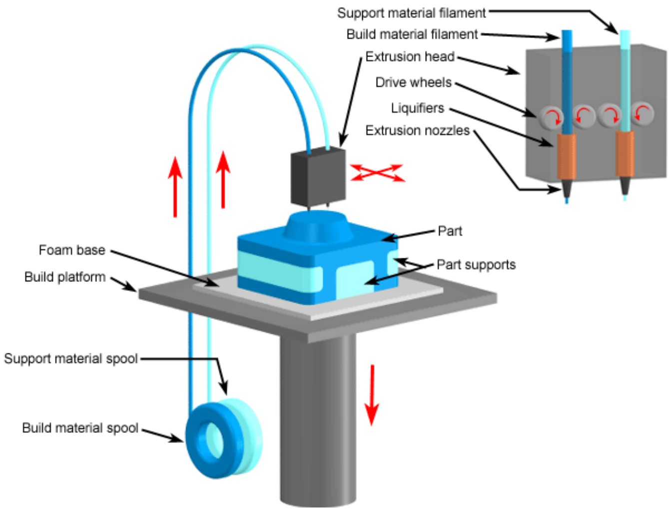
3D tlač je využívaná takmer v každom odvetí, ktoré je pod vplyvom ľudského vedenia. 3D model je využívaný najmä v oblasti architektoniky a bytového dizajnu, pri 3D realizácií budúceho modelu. Takto je množné opísať modely vyrobené zo spomínaného sadrového kompozitu. 3D tlač sa nevyhla ani umeleckému odvetviu. Ocenia ju napríklad reštaurátori, ktorým 3D model poslúži na zobrazenie nenávratného artefaktu kultúry. Slúži aj ako pomoc lekárom či študentom medicíny na dôslednú prípravu operácie, alebo ako možnosť bližšie študovať jednotlivé časti ľudského tela. Je teda fakt, že 3D tlač uľahčuje a zjednodušuje množstvo zložitých a veľmi nákladných procesov a tým prispieva k ich ďalšej inovácii [2].

Technológie 3D tlače

Pod samotnou 3D tlačou rozumieme aditívny postup výroby, t.j. postupné nanášanie materiálu, jeho spájanie až do vzniku naprogramovaného modelu. Dnešné modely 3D tlačiarní využívajú celé spektrum technológií pre 3D tlač.

Fuseddeposition modeling (FDM)

Táto technológia umožňuje stavať objekty s výrobnými termoplastami. Modely sa vyrábajú zahrievaním termoplastického vlákna na danú teplotu topenia a extrudovaním termoplastickej vrstvy po vrstve (Obr. 1).



Obr. 1 Schéma technológie FDM

Na vytvorenie zložitejších štruktúr možno použiť špeciálne techniky. Napríklad tlačiareň môže tlačiť druhý materiál, ktorý bude podporným materiálom pre predmet, ktorý sa tlačí počas procesu prvej tlače. Tento nosný materiál je možné neskôr odstrániť alebo rozpustiť. Toto je najrozšírenejšia a cenovo najdostupnejšia technológia, ktorá je často použitá pri prezentáciách prototypov a vzoriek výrobkov. Tlačiareň vyrába pevné a tvarovo stále modely vhodné presne pre tieto účely [3].

Selective Laser Sintering (SLS) a Direct Metal Laser Sintering (DMLS)

Ide o proces na základe zapekania kovového alebo polymérového prášku vo vrstvách pomocou lasera na požadovaný model. Modely z týchto tlačiarní sú veľmi presné. Samotná prevádzka a obstarávanie týchto tlačiarní býva veľmi nákladná. Časť práškového materiálu, ktorá neprejde spekaním, môže byť použitá na vytvorenie nosnej štruktúry a tento materiál je možné odstrániť po výrobe samotného predmetu na opätovné použitie. S touto technológiou je možné stretnúť sa najmä v automobilovom a strojárenskom priemysle, ale rovnako aj v medicíne.

Electronbeammelting (EBM)

Výstavba modelov pomocou tavenia kovového prášku (zliatiny titánu) vo vrstvách pomocou lúčov elektrónov vo vysokom vákuu. Najväčšou prednosťou tejto technológie je výnimočná presnosť a vynikajúce technické vlastnosti vytlačených výrobkov. Technológia sa využíva v automobilovom, strojárskom priemysle a medicíne, avšak vyhotovenie produktov pomocou tejto metódy je veľmi nákladné [4].

Inkjethead 3D printing

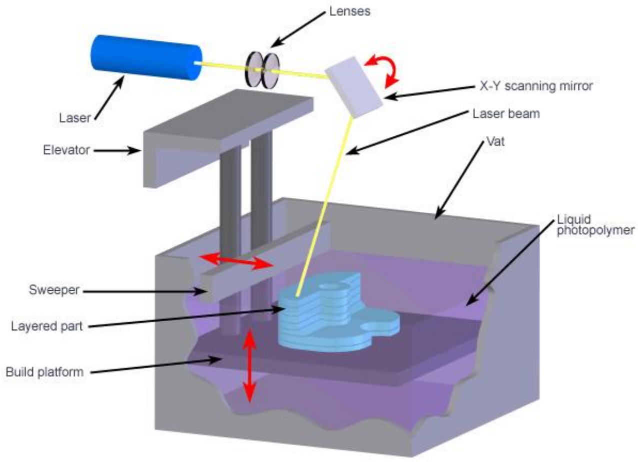
Vytváranie modelu pomocou nanášania tenkej vrstvy prášku (sadra alebo živica) a tlačou spojovacieho lepidla z tlačových hláv (obdoba injektovej tlačiarne). V rámci možností dostupná a ekonomicky výhodná technológia s využitím v modelárstve, architektúre a dizajnérstve. Touto technológiou je možné využiť aj plnofarebnú tlač.

Laminatedobjectmanufacturing (LOM)
Zlepovanie vrstiev lepiaceho papiera, plastu alebo kovovej fólie na seba a následné tvarovanie nožom alebo laserom. Vytvára veľmi presné modely s kvalitným povrchom a náklady na jej obstaranie nie sú príliš vysoké. Tento spôsob je momentálne na ústupe a využíva sa prevažne v architektúre a geografii [5].

PolyjetMatriX
Vytláčanie fotopolyméru tlačovými hlavami a následné vytvrdzovanie (schnutie) pomocou UV lampy. Vytvára modely s veľmi kvalitným povrchom a hodí sa pre vytváranie detailov. Najčastejšie využívané v automobilovom priemysle, elektronike, medicíne, ale pri výrobe odevov.

MultiJetModelling
Vytláčanie vosku tlačovými hlavami. Modely vytvorené pomocou tejto technológie sú presné a detailné, no ich nevýhodou je, že sú príliš jemné, a teda manipulácia s nimi je náročná. Využitie výrobkov vyrobených touto metódou je najmä v konštrukčných kanceláriách na vytváranie menších vzoriek [6].

Stereolitografia (SLA)
Ako východiskový materiál využíva tekutý plast/kompozit (fotopolymér) a tento plast transformuje na 3D objektovú vrstvu po vrstve. Živica je umiestená do kade, ktorá má priehľadné dno. Následne UV laser sleduje stopu tekutej živice od dna nádoby, aby vytvrdil a vytuhol vrstvu živice (Obr. 2).



Obr. 2 Schéma technológie SLA

Spevnená štruktúra je následne ťahaná zdvíhacou plošinou nahor, zatiaľ čo laser vytvára pre každú vrstvu iný vzor pre vytvorenie požadovaného tvaru 3D modelu. Výsledkom sú presné modely s hladkým povrchom. Pomocou tejto technológie je možné vytvoriť prevažne väčšie modely. Nevýhodou tejto metódy je obmedzenosť pri výbere materiálu [7].

Záver

Pomocou najnovších technológií dokáže 3D tlačiareň nanášať tekutý materiál vrstvu po vrstve. Následne vrstvy postupne tvrdnú až do vzájomného spojenia a tým vytvoria finálnu podobu produktu. Tento proces trvá niekoľko hodín. Čas tejto operácie záleží od materiálu, spôsobu výroby a náročnosti modelu na výrobu. Nové technológie sa však snažia tento proces minimalizovať. V budúcnosti bude 3D tlačiareň významným strojom pre akúkoľvek výrobu.

Narastajúca popularita 3D tlačiarní je zapríčinená tým, že za relatívne krátky čas možno vyrobiť takmer všetko z rozličných odvetví, akými sú napríklad bytový dizajn, strojárstvo, či už spomínané zdravotníctvo [8].

Poďakovanie
Tento článok bol vytvorený realizáciou grantových projektov **VEGA 1/0438/20** Interakcia digitálnych technológií za účelom podpory softvérovej a hardvérovej komunikácie pokročilej platformy systému výroby, **KEGA 001TUKE-4/2020** Modernizácia výučby priemyselného inžinierstva za účelom rozvoja zručností existujúceho vzdelávacieho programu v špecializovanom laboratóriu, **APVV-17-0258** Aplikácia prvkov digitálneho inžinierstva pri inovácii a optimalizácii produkčných tokov a **APVV-19-0418** Inteligentné riešenia pre zvýšenie inovačnej schopnosti podnikov v procese ich transformácie na inteligentné podniky.

Použitá literatúra
[1] FUSKO, M. – RAKYTA, M. – KRAJCOVIC, M. – DULINA, L. – GASO, M. – GRZNAR, P. 2018. Basics of Designing Maintenance Processes in Industry 4.0. In: MM Science Journal. No. March (2018), p. 2252-2259. ISSN 1803-1269.
[2] PLINTA, D. – KRAJČOVIČ, M. 2016. Production System Designing with the Use of Digital Factory and Augmented Reality Technologies. In Advances in Intelligent Systems and Computing. Vol. 350 (2016), p. 187-196. ISSN 2194-5357.
[3] CMOREJ, T., PANDA, A., BARON, P., POOR, P., & POLLAK, M. (2017). Surface Finishing of 3d Printed Sample Manufacturated by Fused Deposition Modeling. MM Science Journal, 2017(05), 1981-1985. doi: 10.17973/mmsj.2017_12_201753.
[4] SANIUK, S., SAMOLEJOVA, A., SANIUK, A., LENORT, R. 2015. “Benefits and barriers of participation in production networks in a metallurgical cluster - research results.”, Metalurgija, 54(3), 567-570.
[5] STRAKA M., BINDZÁR P., KADUKOVÁ A. 2014. Utilization of the multicriteria decision-making methods for the needs of mining industry. Acta Montanistica Slovaca. Volume 19, Issue 4, 2014., ISSN 1335-1788.
[6] EDL M., LERHER T., ROSI B. 2013. „Energy efficiency model for the mini-load automated storage and retrieval systems “, International Journal of Advanced Manufacturing Technology, č. 2013, s. 1-19. ISSN: 0268-3768.
[7] IŽARIKOVÁ G. [et al.] 2018. Comparative analysis of the industrial production inside the Euro zone. Interdisciplinarity in Theory and Practice: The Journal for Presentation of Interdisciplinary Approaches in Various Fields. - Arad (Rumunsko): Adoram č. 16 (2018), s. 39-46 [print]. - ISSN 2344-2409.
[8] MARKULIK Š., CEHLÁR M., KOZEL R. 2018. Process approach in the mining conditions / In: Acta Montanistica Slovaca. roč. 23, č. 1 (2018), s. 46-52. - ISSN 1335-1788 Spôsob prístupu: https://actamont.tuke.sk/ams2018.html

Contact address
Ing. Jozef Trojan
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: jozef.trojan@tuke.sk

Review process
Single-blind peer review process.

FYZICKÉ MODELOVANIE VÝROBNÝCH ŠTRUKTÚR POMOCOU 3D TLAČE

Juraj Kováč – Vladimír Rudy– Katarína Kormošová

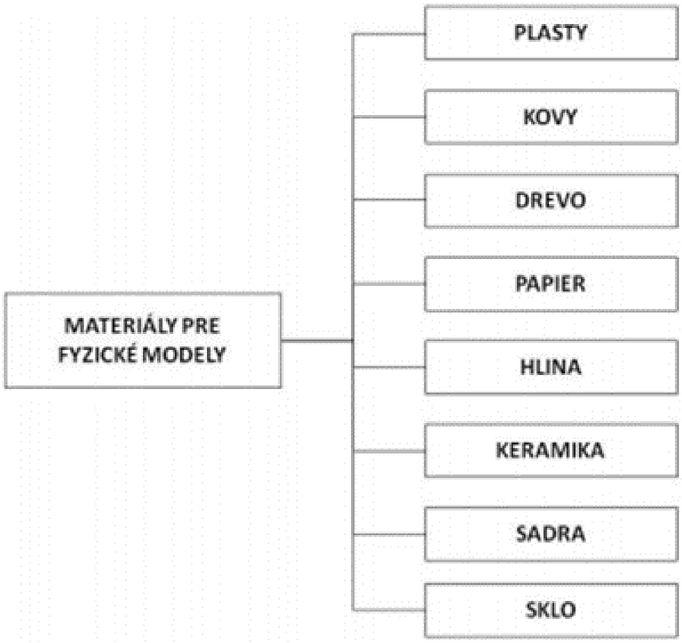
Abstract: Článok sa zaoberá fyzickým projektovaním výrobných systémov. Popisuje možnosti výroby fyzických modelov strojov a ich následné využitie pri projektovaní.
Keywords: Fyzické modelovanie, 3D tlač, projektovanie.

Úvod

Priestorové modely sú nástrojom na lepšie a kvalitnejšie poňatie plánu či projektu. Voči plošným modelom sú kvázi o level vyššou metódou zobrazenia spornej témy. Jestvuje niekoľko metód ich produkcie a materiálov na použitie. Príkladom ich výroby a využitia môžu byť trojrozmerné výtlačky umiestnené v priehladnom plastovom modely na účel demonštrácie zaužívaných i nových spôsobov priestorovej štúdie v strojárskom podniku. Využitie aditívnej výroby v súčasnosti naberá na popularite vďaka terajšej dobe vyžadujúcej ekologickosť a udržateľnosť. Pre svoju všestrannosť nachádza svoje uplatnenie v niekoľkých odvetviach.

1. Fyzické modely a využitie 3D tlače pri ich tvorbe

Model je existujúci objekt, ktorý je do určitej miery zhodný s iným objektom z hľadiska jeho fyzických vlastností a geometrických tvarov. Hlavnou charakteristikou fyzických modelov je to, že sú zhotovené na základe redukcie mierky v porovnaní so skutočnosťou, preto sa tiež nazývajú mierkové modely. Model je teda zmenšená napodobenina nejakého objektu (originálu),a má dve úlohy: byť objektom bádania a slúžiť ako prostriedok pre skúmanie originálu**,** alebo slúži ako demoštratívny model skotočného objektu. Na obr.1 sú uvedené možné materiály pre výrobu zmenšených fyzických modelov.



Obr. 1 Materiály použiteľné pre tvorbu fyzických modelov [3]

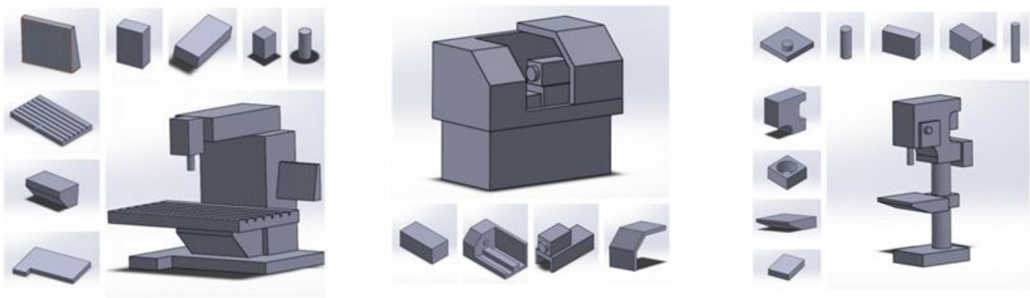
Pre lepšiu analýzu priestoru a jeho riešenia môžu byť nápomocné práve fyzické modely. Tie môžeme chápať ako zmenšeninu výrobného zariadenia či výrobného systému ako celku.Modely môžu poslúžiť ako pomôcka pri projektovaní vtedy, kedy sa možné riešenia na výkrese znázorňujú zložito alebo ich znázornenie je ťažko čitateľné. Taktiež môžu slúžiť ako pomôcka pre lepšiu demonštráciu výsledného riešenia.

Tab. 1 Výhody a nevýhody využívania fyzických modelov pri projektovaní

VÝHODY	NEVÝHODY
Lepšia predstava riešenej problematiky	Nie je istota, že sa reálne dosiahnu lepšie výsledky
Tímová práca	Nutnosť určitých vedomostí a praktických skúseností
Možnosť projektovania pomocou jednoduchých modelov z papiera, dreva,...	Prácna výroba a skladovanie modelov
Rýchla a lacná výroba jednoduchých modelov	Komplikované zaznamenávanie riešení
Sú nápomocné, keď znázornenie na výkresoch je nepostačujúce	Vyššie náklady na výrobu modelov

2. Zhotovenie 3D modelov vo zvolenom programe pre fyzickú výrobu

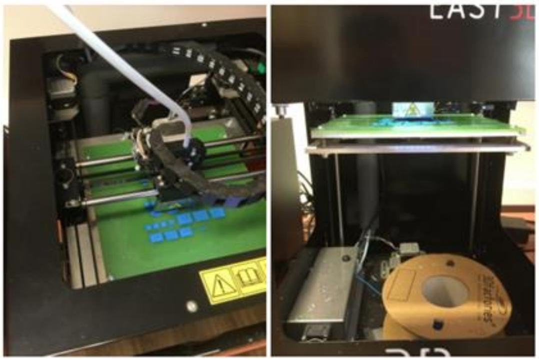
SolidWorks je program pre parametrické plošné a objemové modelovanie vhodný do strojárskeho odvetvia. Umožňuje zhotovenie 2D i 3D návrhov a následne ich rendering do realistických ukážok. Taktiež ponúka možnosť animovania modelov. Svojím jednoduchým užívateľským rozhraním je blízky i bežným používateľom. Okrem toho na rozdiel od iných softvérov nie je tak náročný na procesor, grafickú kartu a pamäť RAM počítača, čím je i prijateľnejší pre počítače so slabšími technickými parametrami. SolidWorks dovoľuje pracovať s návrhom v 3 režimoch. Zaužívaný postup pri ich tvorbe pozostával z nakreslenia základného tvaru kresliacimi nástrojmi, pridania objemu v priestore pomocou nástroja Extrude a úpravy do konečnej podoby zaoblením (skosením), vyrezaním diery či zhotovením škrupiny. Nasledujúce obrázky ukazujú hotové jednotlivé súčasti a ich následné spojenie do výsledného modelu. Tieto výsledné modely je možné uložit vo formate stl pre samotnú 3D tlač fyzických modelov.



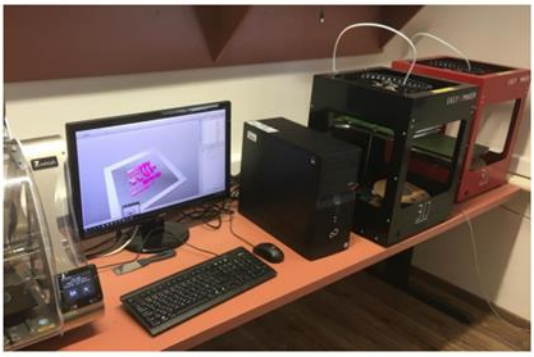
Obr.2 3D model frézky, CNC sústruhu a stlpobej vrtačky [3]

3. Aditívna výroba fyzických modelov strojov

Pred samotnou tlačou sa v programe prislúchajúcom k tlačiarni usporiadajú STL súbory budúcich výtlačkov. Na obrázku 3 možno vidieť, že je možné tlačiť na jeden raz viac kusov modelov v tomto prípade sa z každej súčasti vytvoria tri duplikáty a jednoducho sa rozmiestnia na virtuálnu tlačiarenskú plošinu. Priebeh tlače podľa virtuálnej predlohy a cievka s navinutým vláknom plastového materiálu sú zachytené na obrázku 4. Tlač prebieha v laboratóriu, kde je ku tlačiarňam priradený aj príslušný počítač, viď obrázok 4.

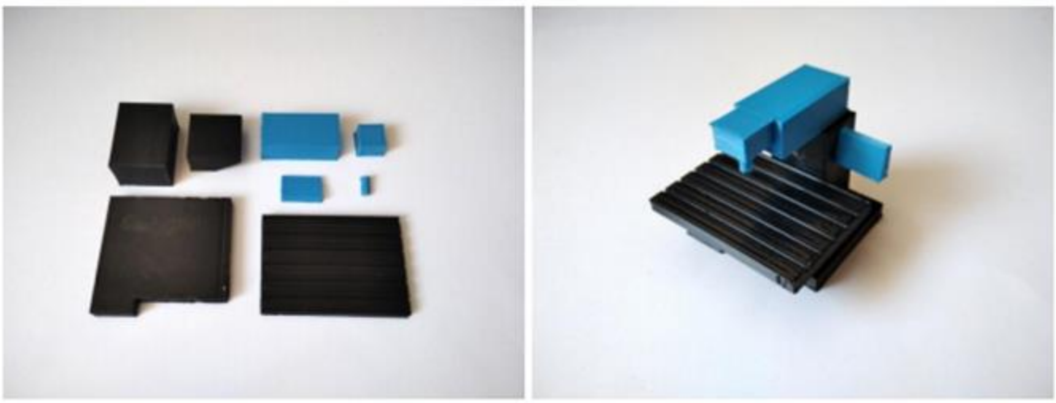


Obr.3 Priebeh tlače modelov

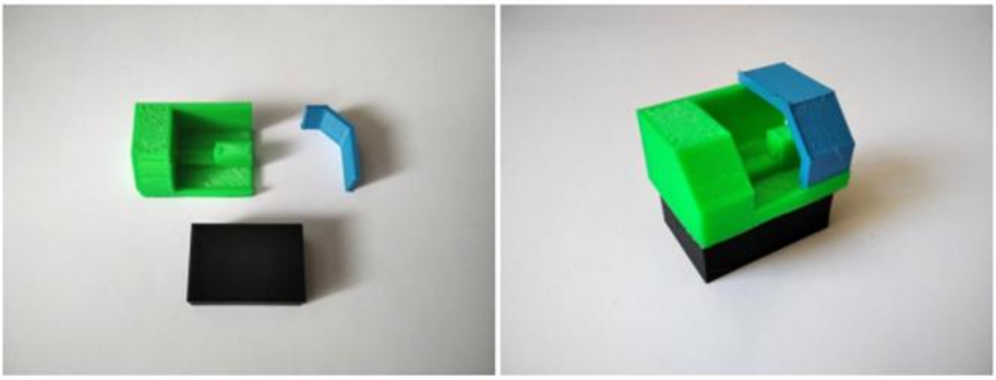


Obr.4.Ukážka pracovného prostredia v procese 3D tlače

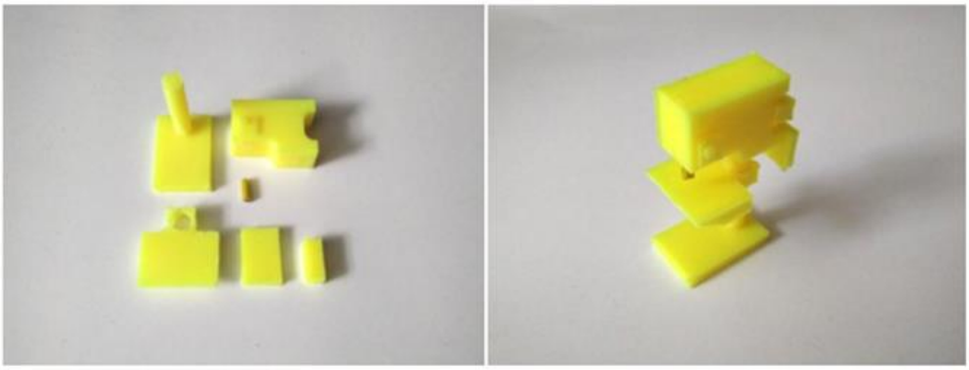
Po vytlačení na modeloch sa môžu vyskytnúť nerovnosti spôsobené tlačiarňou. Zvyčajne sa nachádzajú na prvej vrstve materiálu, ktorá je v priamom styku s tlačovou plochou. Vznikajú v dôsledku stále trvajúceho kvapalného skupenstva materiálu, ktorý sa po tlačiarenskej plošine zľahka rozpustí. Nečisté línie môžu vzniknúť i pri šikmých stenách stúpajúcich do výšky po osi Y.Oboje tieto nerovnosti možno ľahko odstrániť oškrabaním ostrým predmetom či pilníkom.
Tlačiarenské zariadenie si pri tlači pomáha pomocnými vrstvami (vláknami), ktoré pripomínajú tenké, jemné vlásočnice. Tie sú vidieť napríklad pri veľmi blízkom umiestnení komponentov na tlačiarenskej plošine priamo medzi nimi a tiež pri nepravidelných tvaroch na modeloch (oblúky, škrupiny). Keďže sú jemné, dajú sa ľahko odstrániť aj voľnou rukou. Tieto uvedené nerovnosti po odstránení chápeme ako odpad, ktorého množstvo je skutočne minimálne. [3]



Obr. 5 Fyzický model frézky [3]



Obr. 6 Fyzický model sústruhu

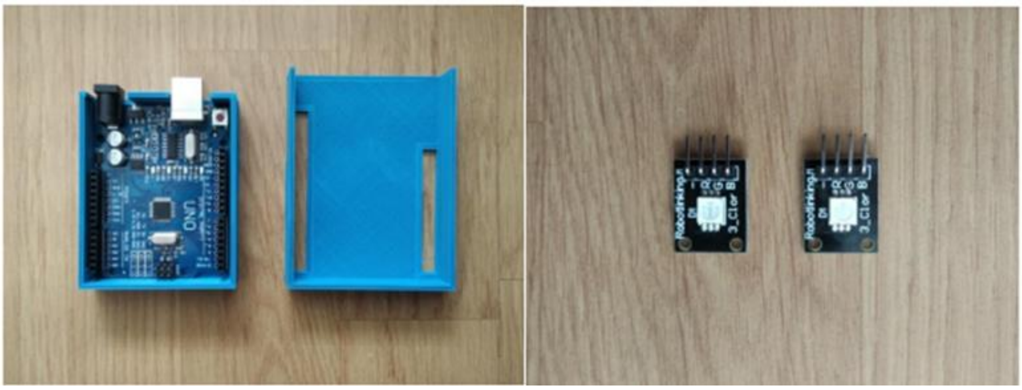


Obr. 7 Fyzický model stĺpovej vŕtačky [3]

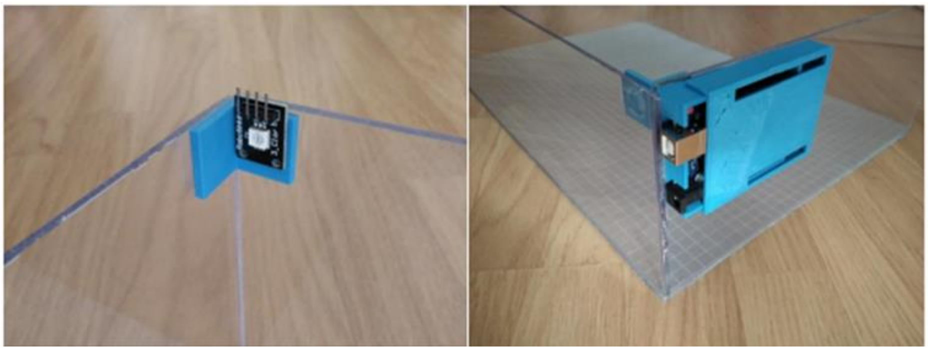
Z každého typu modelu je potrebne vytlačiť viacero kusov. Tým pádom vzniká knižnica fyzických modelov ktorá nájde využitie pri hľadaní riešenia vhodnej dispozície, kedy sa nepotrebné modely môžu odložiť bokom alebo pridať do dispozície výrobného systému.

4. Projektovanie výrobného systému pomocou fyzických modelov

Pri tvorbe dispozičného riešenia pracoviska sa z knižnice vyberá potrebný počet modelov vybraných zariadení, dodržiavajú sastanovené pravidlá vyplývajúce z noriem (vzdialenosti medzi strojmi, od stien a stĺpov, oddopravnej dráhy/dopravníka) atď. Model môže byť vybavený aj RGB ledkami. Tie môžu slúžiť ako svetelná signalizácia pri výskyte prepravného zariadenia na dopravnej dráhe.

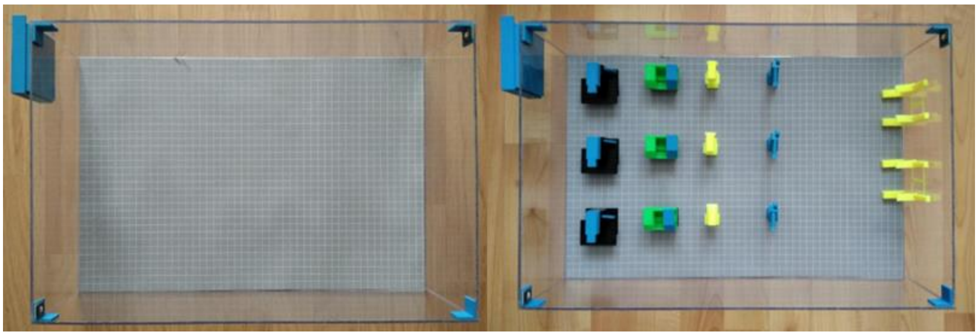


Obr. 8 Riadiaca doska arduino a RGB ledky[3]



Obr. 9 Detailný pohľad na umiestnenie RGB lediek a arduina [3]

V rámci umiestnenia fyzických modelov výrobných prostriedkov je potrebné zvoliť výber mierky rastra pôdorysnej plochy určenej pre riešenie štruktúry výrobného systému kvôli priestorovej lokalizácii kritických plôch a ich 2D identifikácii (dvere, rozvody energií a pod.). [1]



Obr.10 pohlad z hora na raster výrobnej plochy [3]

Príklad fyzyckého projektovania výrobného systému v edukačnej činnosti študentov je uvedený na obr. 11. Fyzické projektovania umožnujé aplikovať timovu prácu projektantov, alebo študentov. V krátkom čase meniť a upravovať dispoziciu strojov a vytvárať varianty usporiadania výrobného systému.

Obr.11 Aplikácia systému modelového projektovania výrobných systémov v tréningovom procese výučby [2]

Záver

Fyzické modely a fyzické projektovanie môžu byť náročné po časovej stránke, prácne na výrobu, ale výsledok vždy prinesie nejaký vedomostný, praktický aj edukatívny prínos. Okrem iného sú udržateľné, dajú sa využiť opakovane, prislúchajúca knižnica sa môže ďalej rozširovať o ďalšie modely, ktoré môžu, ale nemusia spadať aj do iného než strojárskeho odvetvia.

Poďakovanie
Tento príspevok bol vytvorený ako výstup grantového projektu KEGA 002TUKE-4/2020 „Implementácia inteligentnej techniky a pokrokových technológii pre podporu transformačných procesov a projektovanie výrob budúcnosti“.

This article was created by implementation of the grant project KEGA 002TUKE-4/2020 “Implementation of intelligent technology and advanced technologies to support transformation processes and future product design”.

Literatúra

[1] KOVÁČ, J. 2006. Projektovanie výrobných procesov a systémov. Košice: Technická univerzita v Košiciach, Strojnícka fakulta. Edícia EQUAL. 139 s. ISBN 80-8073-720-7.
[2] KOVÁČ, J. – RUDY, V. – KOVÁČ, J. 2018. Metodika projektovania výrobných procesov 2.Inovačné projektovanie výrobných systémov. Košice: Technická univerzita v Košiciach, Univerzitná knižnica. Edícia vedeckej a odbornej literatúry. 240 s. ISBN 978-80-553-2873.
[3] Kormošová,K.,Fyzické modelovanie výrobného pracoviska pomocou 3D tlače, Sjf TUKE. Bakalárska práca 2020 Košice.
[4] RUDY, V. – MALEGA, P. – KOVÁČ, J. 2012. Výrobný manažment. Košice: Technická univerzita v Košiciach, Strojnícka fakulta. Edícia študijnej literatúry. 147 s. ISBN 978-80-553-1265-1.

Contact address
Ing. Juraj Kováč, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: juraj.kovac@tuke.sk

Review process
Single-blind peer review process.

Trendy a inovatívne prístupy v podnikových procesoch „2020“, roč. 23
Trends and Innovative Approaches in Business Processes “2020”, Vol. 23

PERFORMANCE MEASUREMENT AND PERFORMANCE INDICATORS

Michaela KOČIŠOVÁ – Jaroslava KÁDÁROVÁ – Laura LACHVAJDEROVÁ

Abstract: In this article we discussed the principles of performance measurement and evaluation in performance management. We are interested in performance indicators as key performance indicators. Key Performance Indicators are one of the most powerful tools available to enable companies to achieve performance improvement which should be a core goal of any performance management system.
Keywords: Performance measurement, Performance management, Performance measure, Performance indicator.

Introduction

The definition of Corporate Performance Management - CPM has been consistent since industry analysts Gartner Research introduced CPM in 2001. CPM is an umbrella term that describes all of the processes, methodologies, metrics and systems needed to measure and manage the performance of an organization. CPM is used for monitoring, performance control and efficiency of companies. CPM means an integration and automation of Scorecarding, Business intelligence (or decision support), including financial reporting and consolidation, Planning. These technologies are as key to CRM’s value in letting organizations answer the essential business decisions.

Performance measurement

A **controllable performance measure** reflects the consequences of the actions taken by the decision maker. Intuition suggests that we hold decision makers accountable only for costs and benefits that they can control that is, costs and benefits that change because of their actions. Thus, we should hold a production manager accountable for production delays but not for the overall volume of production.

Marketing managers have the authority to change prices and offer promotions that affect actual sales, which determine the required production.

Production managers, therefore, have little control over the volume of production. It is not reasonable to hold them accountable for someone else’s decisions or random market conditions. Likewise, the manager of a restaurant in a beach resort can do little to avoid losses due to a hurricane.

While intuitive, the controllability principle is not always the right approach for choosing performance measures. Instead, we should rely on the **informativeness principle**. A performance measure is *informative* if it provides information about a manager’s effort, even if the manager does not have control over it.

Most controllable measures are informative. Students control their performance on a quiz, and their score is informative about their grasp of the subject matter. However, an informative measure is not necessarily controllable. Consider the practice of grading on a curve, in which a student’s grade also reflects overall class performance. What does this relative grading accomplish? Well, it controls for the level of difficulty of the exam. In an exam where the top score is 70 out of 100, a score of 69 is a high mark. An individual student has little control over

how the rest of the class performs. Yet, the overall class performance is useful information in evaluating each individual student's performance because it tells us how hard the exam is.
This example extends readily to business settings. If a firm incurs losses when other firms in the industry are highly profitable, we may attribute those losses to poor managerial performance. However, if other firms in the industry are doing even worse, then the firm's management may actually be doing a terrific job of dealing with adverse business conditions. Thus, evaluating a firm relative to other firms in the industry, or **relative performance evaluation**, is useful, even though the firm's managers may have little control over how other firms do.
An ***ideal performance measure***:

- Aligns employee and organizational goals.
- Yields maximum information about the decisions or actions of the individual or organizational unit.
- Is easy to measure.

Is easy to understand and communicate.

A single performance measure rarely possesses *all* of these characteristics. Rewarding employees based on customer satisfaction can help align organizational and employee goals. The measure motivates employees to pay attention to customers, and happy customers are the sources of future profit. But, customer satisfaction is subjective and difficult to measure. Some school districts rely heavily on objective test scores to evaluate the performance of their employees (such as grade school teachers). These scores might divert employees' attention from building other important skills such as creative thinking, which are hard to measure. To make effective trade-offs among the attributes, organizations often use a combination of performance measures. Let us apply these principles to KCPC and select performance measures for its cost and profit centers.
Cost center managers serve two roles in organizations: achieving cost targets for a given level of output in the short term, and making continuous efficiency improvements to cut costs in the long term.
Organizations typically use budget variances to measure cost center performance. Operating budgets specify the resources needed to achieve a targeted level of output or service for the plan period.
The budget makes assumptions about materials usage and prices to determine the expected quantities of raw materials and their costs. We analyzed flexible budget variances to evaluate performance during a budget period. For example, we can employ usage variances to evaluate the Production Department and raw material price variances to evaluate the purchasing function.
Ever since Aaron began KCPC, he has followed a practice of making detailed budgets for each branch. These budgets specify expected sales volume by product and the costs of providing the requisite service. At the end of each week, Aaron performs a variance analysis, by branch, to highlight problem areas and institute immediate corrective action.
To achieve long-term reductions in cost, organizations use performance measures arising from techniques such as benchmarking and kaizen.

Tab. 1 Performance measurement [6]

Concepts and systems for performance evaluation		
Strategic Planning	Strategic Alliances	Open Innovation
Mission and Vision Statement	Customer Segmentation	Price Optimization Models
Customer Relationship Management (CRM)	Knowledge management	Downsizing
Balanced Scorecard (BSC)	Scenario and Contingency Planning	Data Envelopment Analysis (DEA)
Benchmarking	Satisfaction and Loyalty Management	Performance management processes by Sink and Tuttle
Outsourcing	Supply Chain Management (SCM)	Performance pyramid
Change management	Risk management	Rapid Prototyping
Core Competencies	Mergers and Acquisition	Social Media Program
Six Sigma	Lean Thinking	Theory of Constraints
Kaizen	Total Quality Management	Pay for Performance (P4P)

Benchmarking is a process that involves comparing the effectiveness and efficiency of various activities and business processes in a firm against the best practices in the industry. Such best practices are not controllable by the decision maker but still are useful performance measures. For example, a firm may hold a manager accountable for achieving greater reductions in cycle time than attained by immediate competitors.

Kaizen is a philosophy of continuous improvement. This initiative encourages and rewards employees who constantly seek and suggest improvements to activities and business processes. One way to implement continuous improvement is to hold managers accountable for achieving permanent cost reductions. Within KCPC, Aaron has tried to instill a spirit of continuous improvement. He routinely benchmarks the costs in one branch versus the others. If a branch consistently turns in a poor performance, Aaron steps in to help the manager find ways to reduce costs. Each month, Aaron also recognizes the employee with the “best cost saving idea for the month,” and implements the idea in all branches. On an inflation-adjusted basis, his goal is to obtain a 5% reduction in overall costs each year.

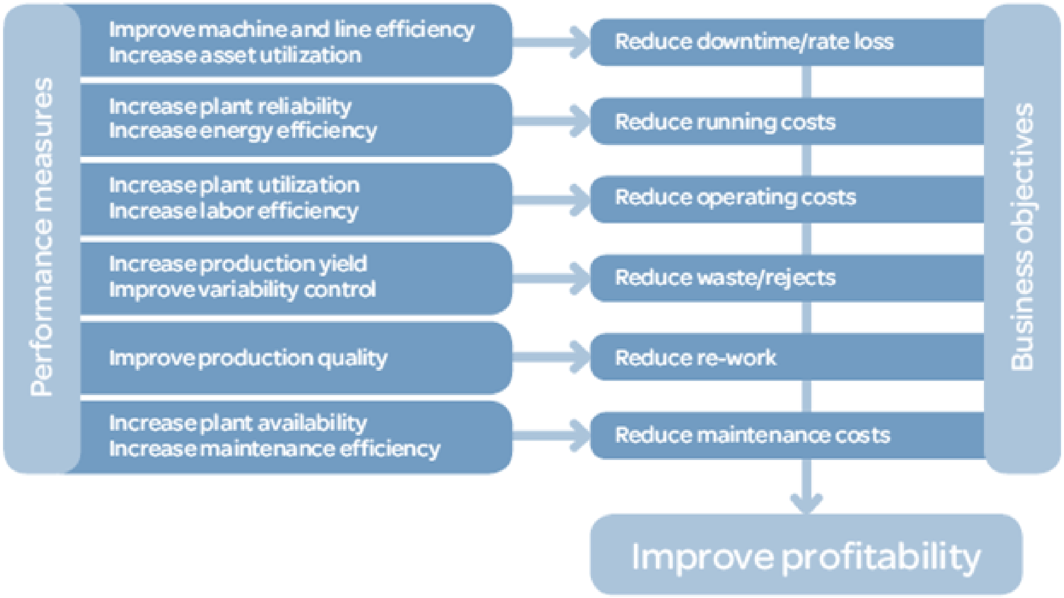


Fig. 1 Relations between profitability improving [11]

Efficiency is a relative measure and efficiency score depend on the companies, which are compared. The measurement of relative efficiency where there are multiple possibly incommensurate inputs and outputs was addressed by Farrell and developed by Farrell and Fieldhouse, focusing on the construction of a hypothetical efficient unit, as a weighted average of efficient units, to act as a comparator for an inefficient unit.

Key Performance Indicators

Key Performance Indicators (KPIs) help companies understand how well they are performing in relation to their strategic goals and objectives. They describe some form of data quantification and performance metrics used to performance measuring.

Fig. 2 Performance measurement [4]

Process of **Performance measurement** includes three fields:

1. Measuring for learning and improvement is the most natural form of using KPIs and something we do every day in our daily lives. The aim is to equip our employees with the

information they need to make better informed decisions that lead to improvements. In this context, KPIs are used internally as the evidence to inform management decisions, to challenge strategic assumptions and for continuous learning and improvement.

2. Another reason for collecting KPIs is to inform external stakeholders and to comply with external reporting regulations and information requests. When measuring for external reporting and compliance purposes, any reports and associated indicators either have to be produced on a compulsory basis such as annual financial statements, accounts, or performance reports for regulators.
3. Measuring to control and monitor people - KPIs can also be used to guide and control people’s behaviors and actions.

For clearly identifying the information needs and then carefully designing the most appropriate **performance indicators** the **ICE approach** is often used.

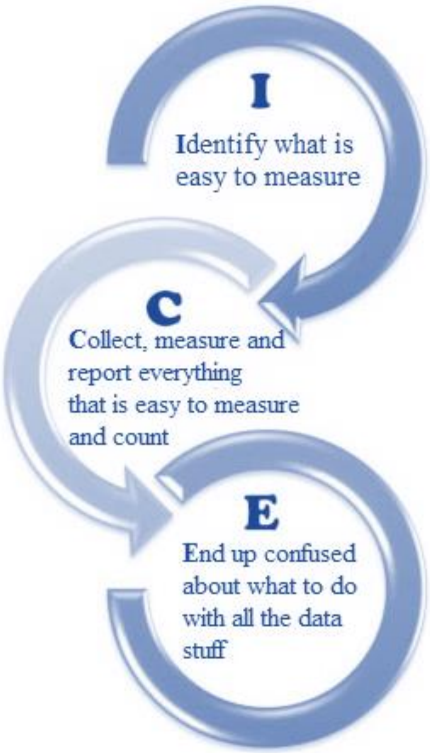


Fig. 3 ICE approach [4]

Key Performance Indicators are one of the most powerful tools available to enable companies to achieve performance improvement which should be a core goal of any performance management system. But using KPIs appropriately comes replete with challenges. KPIs should be primarily deployed for learning and improvement and not for command control. When KPIs are used inappropriately they also become the most resisted of management tools.
Selecting and implementing effective KPIs is important for any company. Without good KPIs a company has no way to measure their performance in relation to their strategic goals.

Conclusion
Currently, there are many the strategic tools and systems for the evaluation of the company performance. Only a company that meets the predefined objectives defined in the strategy can be considered as efficient and executive in the long term. Performance effectiveness is about

executives having all necessary information when they make long-term decisions about the strategic direction of the company. It is also about strategic planning, removing constraints, and helping the executive level set new targets and goals. The gains promised by a CPM vision are realized by the automated and integrated CPM system.

Acknowledgements
This artical is the result of the projects implementation: Project KEGA 009TUKE-4/2020 Transfer of Digitization into Education in the Study Program Business Management and Economics, KEGA 001TUKE-4/2020 Modernizing Industrial Engineering education to Develop Existing Training Program Skills in a Specialized Laboratory.

References
[1] ČARNICKÝ, Š., FEDORKO, V.: Corporate Performance Management. In: Moderní řízení, č. 2, roč. 2005.
[2] KÁDÁROVÁ, J.: Evaluation in the performance management. In: Transfer inovácií. č. 32, 2015, s. 257-260. ISSN 1337-7094.
[3] KÁDÁROVÁ, J.: Factors that impact rate of return on assets. In: Intercathedra. No. 26, 2010, Kaplan, R.S., Norton, D.P.: Balanced Scorecard - Strategický systém měření výkonnosti podniku. Management Press, 2007. ISBN: 80-7261-177-5.
[4] KOVÁČ, J., KÁDÁROVÁ, J., DURKÁČOVÁ, M.: Performance management and key performance indicators. In: Transfer inovácií. č. 24, 2012, s. 4-8. ISSN 1337-7094.
[5] LIBERKO, I., JANEKOVÁ, J., VIDOVÁ, J.: Approaches to measurement of company performance. In: Intercathedra. No. 21, 2003, p. 50-52. ISSN 1640-3622.
[6] MIHOK, J., VIDOVÁ, J.: Corporate performance management as a new way in directing companies. In: Acta Montanistica Slovaca. Roč. 11, č. 4, 2006, s. 278-282. ISSN 1335-1788.
[7] RAŠNER, J., RAJNOHA, R., SUJOVÁ, A.: Management, costing and budgeting on the process basis. The growth and development in forestry and wood industrie. Scientific book. Zagreb, Croatia, 2004. ISBN 953-6307-73-1.
[8] TEPLICKÁ, K.: Moderné trendy v manažérskom účtovníctve," ES F BERG TU v Košiciach, Košice, 2012. ISBN 978-80-553-0916-3.
[9] VIDOVÁ, J.: Metodika riadenia organizačnej výkonnosti = Metodology of corporate performance management. In: Faktory podnikovej úspešnosti v podmienkach európskeho agrárneho trhu. Nitra: SPU, 2005, s. 496-500. ISBN 8080696152.
[10] WAGNER, J.: Merění výkonnosti, Jak měrit, vyhodnocovat a využívat informace o podnikové výkonnosti. Praha: Grada Publishing, a.s., 2009. 256 strán. ISBN 978-80-247-2924-4.
[11] ZHU, J.: Quantitative Models for Performance Evaluation and Benchmarking: Data Envelopment Analysis with Spreadsheets, Springer Science +Business Media, LLC, 2009.

Contact address
Ing. Michaela Košičová, PhD., MBA
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: michaela.kocisova@tuke.sk

doc. Ing. Jaroslava Kádárová, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: jaroslava.kadarova@tuke.sk

Ing. Laura Lachvajderová
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: laura.lachvajderova@tuke.sk

Review process
Single-blind peer review process.

ECONOMIC INFORMATION FOR PERFORMANCE MEASUREMENT

Jaroslava KÁDÁROVÁ – Michaela KOČIŠOVÁ – Martin TREBUŇA

Abstract: The basics resources of the financial and economic information are financial statements. There are three financial statements: the balance sheet, the income statement and the cash flow statement. The balance sheet represents the funding and financial position of the business, the income statement represents the performance of the business and the cash flow statement represents the health of the business. The financial statements are prepared according to accounting principles and conventions.

Keywords: Economic information, Performance measurement, Balanced sheet, Income statement, Cash-flow.

Introduction

To be successful executives must be more knowledgeable than ever as they select the right management tools and information for their companies. The selection process itself can be as complicated as the business issues they need to solve. They must choose the tools and information that will best help them make the business decisions that lead to: (1) enhanced processes and products, (2) result in superior performance and profits. Successful use of such tools and information requires an understanding of the strengths and weaknesses of each tool as well as an ability to creatively integrate the right tools, in the right way, at the right time.

Organization of the economic center

Organizations need effective performance measurement systems, to evaluate the decisions of various responsibility centers and to set appropriate incentives for their managers. Indeed, Aaron’s problem at KCPC is the lack of such a system. *What* should Aaron measure to evaluate performance? *How* should he measure the chosen items? *How* should he use these measures in incentive contracts? Let us address these questions next.

The finance department of a company or corporation usually has two major functions:

- The treasury that is responsible for managing the cash and investments of cash in the financial markets (marketable securities) and managing the company’s debt.
- The controller that is responsible for functions like cost accounting, financial accounting, and tax.

The chief financial officer (CFO) is responsible for both of these functions. Another function within the domain of the CFO is broadly called the financial management of a company. **Financial management** aims to maximize value for the shareholders while managing the risk profile of the company. The opportunities for the financial manager to create value for the company are in arranging the company’s financing efficiently and in using these finances effectively. As a result, the type of decisions required of financial managers can be classified as either financing decisions or investment decisions.

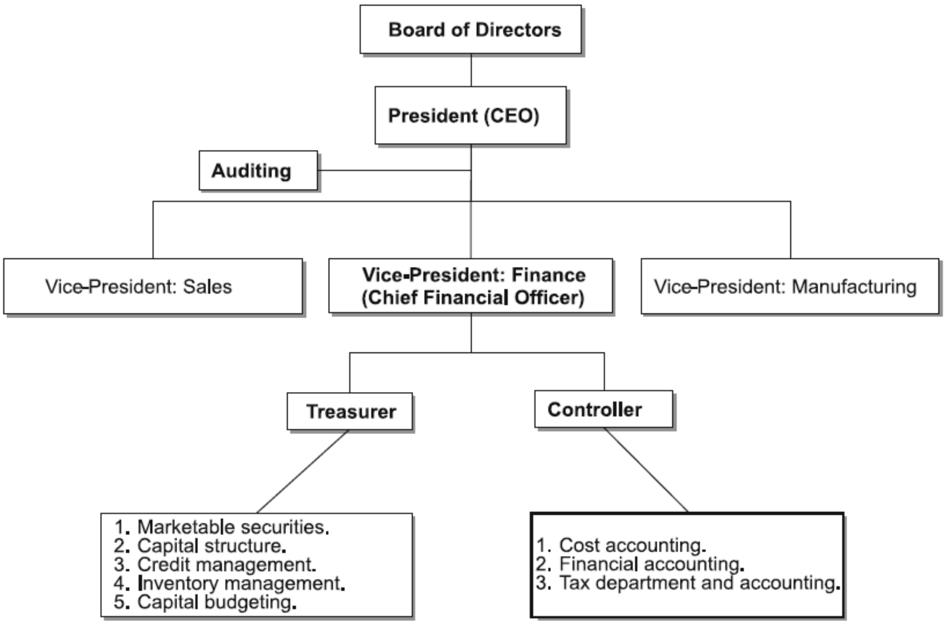


Fig. 1 Functional roles of the finance in a company [3]

The above discussion focuses on evaluating cost centers for which there is a clear relation between inputs and outputs. Such centers are termed **engineered cost centers**. However, many managers oversee **discretionary cost centers** where measuring output can be difficult. For example, members of the corporate legal staff guide and counsel management, but their output is intangible as it pertains to the quality of corporate decisions. Because there is no obvious relation between inputs and outputs in discretionary cost centers, the concerned managers’ evaluation is primarily subjective. Often, the manager is required to operate within a fixed budget set at top management’s discretion. The manager also is responsible for meeting qualitative targets, such as promptness in responding to inquiries or anticipating and heading off problems. Being relatively small, KCPC does not have many discretionary cost centers. Aaron has outsourced most services such as accounting, advertising, IT support, and legal. Periodically, he evaluates the efficiency and effectiveness of the purchased services by obtaining competing price quotes and querying his managers about their satisfaction with the level of service.

As shown in Figure 2, let us consider in detail the three common forms of **responsibility centers** listed below. Each of these organizational subunits corresponds to the nature of decisions made by the managers of the subunit.

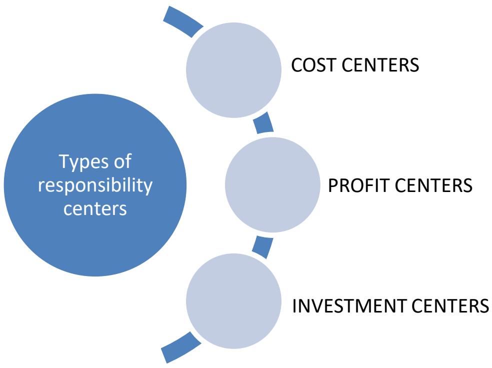


Fig. 2 Types of responsibility centers [2]

Let us now review the decision rights delegated to each type of responsibility center. In this article, we focus on the first issue of how to pick performance measures for each kind of responsibility center.

Cost Centers
Cost center managers exercise control over costs, but not revenues and investments. Their charge is to *minimize the cost of producing a specified level of output or the cost of delivering a specified level of service*. The objective of cost center managers is to improve the *efficiency* of operations by finding ways to cut costs and minimize waste.
Examples of cost centers include departments such as plant maintenance, data processing, human resources, production, and general administration. We could also consider departments such as machining and assembly, both of which are involved in making product, as cost centers. In KCPC, copy operations and PC operations in each location are cost centers.

Profit Centers
Profit center managers focus on profit. Their goal is to *both minimize costs and to maximize revenues*. KCPC’s operations in each of the three regions are profit centers. Other examples include individual product lines in firms such as Procter and Gamble and retail stores of firms such as Sears.

Investment Centers
Managers of investment centers make decisions that influence costs, revenues, and investments. Their mandate is to maximize the returns from invested capital, or to put the capital invested by owners and shareholders of their organizations to the most profitable use.
Examples of investment centers include large independent divisions in organizations such as Sony, Siemens, Microsoft, and Procter and Gamble. In the case of KCPC, the only individual with control over investments is Aaron, as he has not delegated this authority to any of his managers.

Information flows in the companies

The aim of a company is to meet a market need. Purchasing the company’s products will satisfy the customer’s needs. In order to provide this product or service, the company embarks on a project that requires a production facility to manufacture the product and a distribution network to bring the product or service to market. The company requires capital for the acquisition of the assets to do this. The company raises the capital it requires from two main sources:

- Shareholders that are part owners of the company. They are rewarded for the risk they take in investing in the company through the increased value of the company (the capital gain), and through regular cash payments made by the company (the dividends).
- Debt-holders require the loan to be repaid in full, and are rewarded for the risk that they take by earning interest at regular intervals on the loan. The company’s lenders loan money to the company. A loan is also called debt, and the lenders are also called debt-holders.

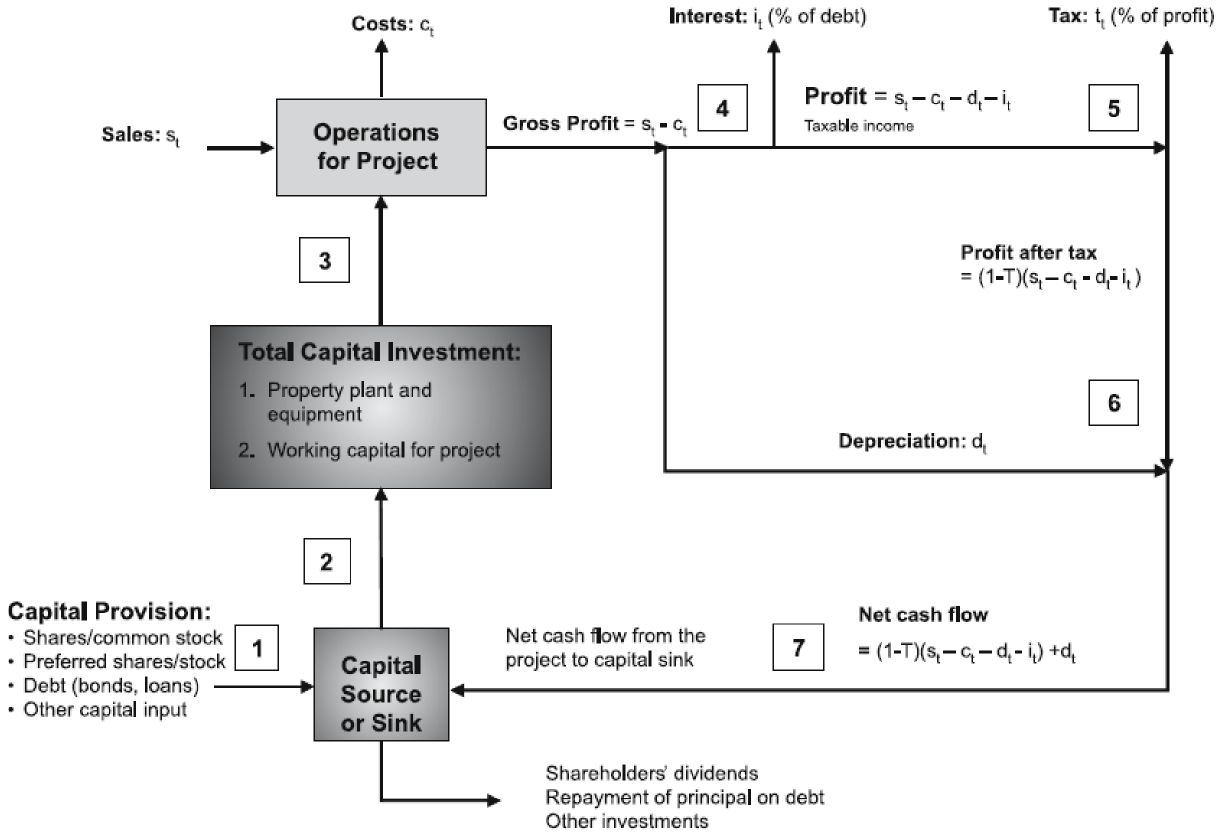


Fig. 3 Flow diagram representing the investment and operating transactions of the company [4]

In addition to raising capital from shareholders and debt-holders, the company can obtain short-term finance from **creditors** in the form of the credit terms offered by **suppliers**. The capital that is raised from **investors** is used to meet the market need by building the production facility, making the product, and selling the product to customers for more than it costs to make the product. The business does this so that it can pay taxes, repay the interest and principal on loans to the debt-holders, retain some earnings for the future, and pay the shareholders a return in the form of a dividend. The activities of the company and the profit from these activities benefit society through the meeting of the customer’s need and the employment of people, benefit the government through the paying of taxes, benefit the banks and other debt providers through the paying of interest, and benefit the shareholders through the paying of dividends and the increased value of the company.

Basic statements in the companies

The interaction of capital and profit shown in Figure 4 is the basis for the development of the balance sheet and the income statement.

The reporting “domain” for both the income statement and the balance sheet is shown in Figure 4.

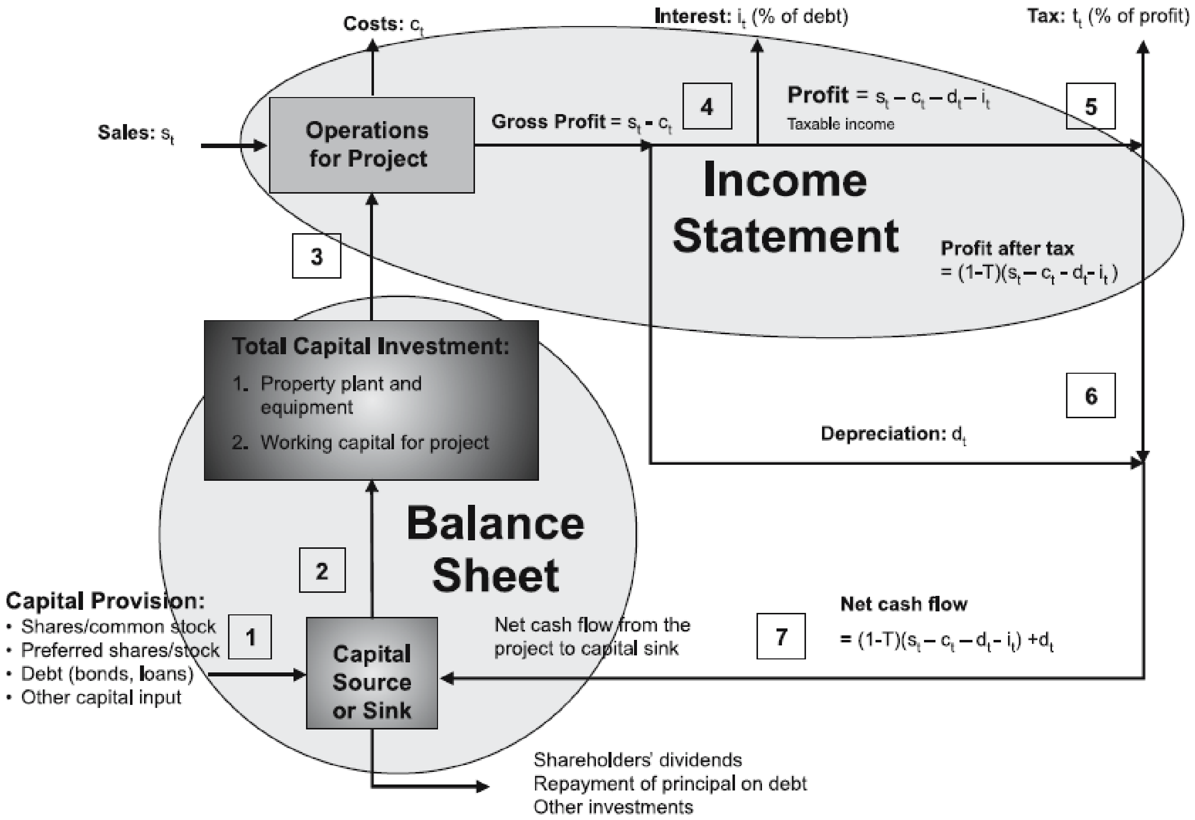


Fig. 4 The areas of interest to the income statement and balance sheet in reporting the company’s transactions [4]

The financial statements are prepared for a reporting period. The balance sheet, which represents conserved quantities because of the dual nature of transactions, is the balance from the beginning of the company’s life to the reporting date. The income statement and the cash flow statement do not represent conserved quantities, and are therefore balances between two points in time, that is, from the beginning of the reporting period to the end of the reporting period.

Income Statement

The purpose of a business is to create value by making a profit. The income statement, also known as the “profit and loss” account reports how much profit a business has made during a particular period of operation, known as the reporting period.

In order to determine the profit, the revenues and the expenses must be identified. The **revenues**, the result of a cash sale or a credit sale, may be generated in different ways depending on the nature of the business. For a manufacturer, this is the amount received for the sale of the manufactured goods; for an engineering consultancy, this is the fee received for the services; for a bank, this is the interest received on loans.

The **expenses** represent the out-flows incurred in generating the revenues. In the same way in which revenue can be a result of cash or credit sales, expenses may result in direct cash out-flows or in increases in the liabilities. Expenses are the costs of purchasing the raw materials that are transformed into the company’s products, as well as the salaries and wages, advertising, rent, transportation, insurance, telephone and many others costs of doing business.

The **profit** is the difference between the total revenue for the period and the total expenses for the period. If this is negative, that is, the expenses exceed the revenues, and then a **loss** is incurred.
The format of the income statement may vary depending on the business and the financial reporting standards of the country in which the business is incorporated.
There are slight differences in the format of the income statement and the profit and loss account. Usually the values for the current reporting period and the previous period are given, enabling the comparison of the performance of the company in the current period with that in the previous period.
The expenses are separated in more useful categories than lumping them all. These different categories will be discussed in the order that they are usually found in the income statement.
The first section of the income statement is concerned with calculating the gross profit (also called gross margin). The Revenue, or Sales, is the first item in the income statement, and the Cost of Sales, or the Cost of Goods Sold, follows this item. The costs of goods sold are the direct costs incurred in the delivery of the product or the service to the customer. The difference between the Revenue and the Cost of Goods Sold is the gross margin or gross profit.
The next section of the income statement is concerned with the Overheads or the Selling, General and Administrative category. These are the expenses other than the direct costs of producing the company’s products or services that are incurred in the running of the business. They include the distribution costs of the product, the costs of the marketing and the sales departments, finance and administration costs, and research and development costs.
The final section involves the deduction of interest, depreciation (if it hasn’t been included in the overheads) and taxation. The figure arrived at is the net profit, or “bottom line,” which indicates how much value the company has created during the period.
The income statement can be derived from Figure 3 and reported in the same order in which it was discussed. Thus beginning with the operations, following the flow diagram around to net profit, the income statement for the company.

Balance Sheet

The income statement measures performance of a company over the reporting period; the balance sheet reports the value of the company at a point in time. It details the forms in which the wealth of the company is held, and how much is held in each form. The balance sheet is an implementation of the accounting equation, in which assets of the business are balanced by the claims against the business. It was shown in that section that the claims against a business are of two types, the liabilities of the business, and the owners’ equity. Before we examine the format of the balance sheet, we need to examine each of these terms.

- **Assets** are the resources that have monetary value and are owned by the business. The value of an asset can arise through its use, or through its hire or sale. An obsolete piece of equipment that can be sold for scrap is an asset, while that which cannot be sold is not an asset. The owner must have an exclusive right to or control of the asset and the transaction that resulted in this right must have already been concluded. Assets are normally divided into two categories:
- **Fixed assets**, or non-current assets, are tangible items that are acquired for the purpose of being used to generate revenue (rather than for resale). Fixed assets are the equipment used by the business in generation of the company’s products; they are not consumed quickly during their use. Typical fixed assets are items like land, buildings, plant and equipment, fixtures and fittings, and vehicles. Most companies will have an authorisation procedure for the acquisition of fixed assets. Although definitions will differ from one organisation

to another, this procedure is commonly known as capital expenditure. The value of a fixed asset represented on the balance sheet is the “book value,” that is, the original cost of the asset less the accumulated depreciation.

- **Current assets** are those items that can or will be turned into cash relatively quickly, that is, in less than a year. For example, the company purchase stock, and sells the product to the customer on credit. These two transactions involve three items that are current assets: cash; stocks or inventory; and debtors. The stock is purchased with cash and the product sold on credit increases the debtors. (Debtors still owe the company for the products they have purchased from the company. Debtors are also called accounts receivable.)
- **Liabilities** represent claims that others, except the owner of the business, have against the business. These claims usually arise from lending money to the business, or supplying goods to the business on credit terms. Once a liability has been incurred, it remains an obligation of the business until it is settled. The liabilities are divided into current liabilities and long-term liabilities. Long term liabilities are not due for more than a year, whereas current liabilities are due within a year. Long-term liabilities are items such as loans, while current liabilities are items such as creditors and the bank overdraft. Creditors, to whom the company owes money for the supply of stock, are sometimes called accounts payable.
- **Equity** in a business is the amount that is owed to the owners or shareholders of the business. The equity arises from two main mechanisms:
  - The capital that was raised from shareholders and owners to start the business. The investment by the owners of the business is called the share capital or the common stock on the balance sheet.
  - The profit earned by the business and not paid out to the shareholders.

The profits that are retained by the company (that is, not paid to the shareholders) are called the reserves or retained earnings. Thus the retained earnings or profits are the sum of all profits made by the company during its history less all the dividends paid to the shareholders during the company’s history.
The relationship between these categories is given by the accounting equation, which is expressed as follows:

$$Assets = Liabilities + Equity \quad (1)$$

Since the assets are comprised of fixed assets and current assets and the liabilities consist of long-term liabilities and current liabilities, the accounting equation can be expanded to give the following equation:

$$(Fixed\ Assets) + (Current\ Assets) = (Long\ term\ Liabilities) + (Current\ Liabilities) + Equity \quad (2)$$

The difference between current assets and current liabilities is called the working capital.

Cash Flow Statement

The income statement provides a view of the business based on the revenue and expenses, not the cash receipts and payments. Because accrual accounting is used and because profit includes non-cash items such as depreciation, there may not be a one to- one relationship between profit and cash. It is possible for a profitable company to go out of business due to a shortage of cash; indeed, a shortage of cash is the most common cause of business failure. A shortage of cash in a business is referred to as commercial insolvency.

The cash flow statement is a formal statement of the cash payments and receipts for the reporting period. The cash flow statement, shown in Figure 19, represents the cash generated or consumed in the operating, investment and financing activities of the business.

- **Operating activities** - The operating cash flow represents the cash received from customers and cash paid to suppliers and employees. There are two methods for determining the cash flow from operating activities: the direct method and the indirect method. The direct method involves separating all the cash transactions into those that involve operating activities and those that do not. The indirect method determines the cash generated by calculation from profit (net income) obtained from the income statement. The indirect method is the method most adopted in practice. The operating cash flow is calculated by adjusting the net income for two things: the non-cash items, such as depreciation, and the change in working capital.
- **Investment activities** - Investing activities report the acquisition or disposal of long-term assets. The change between the current period and the previous period in the fixed assets on the balance sheet represents the change in the cash position as a result of investment activities by the company. This is given by the following expression:
- **Financing activities** - The company can raise funds for its activities from a combination of equity and loans. The financing activities of the cash flow statement reflect these activities of the company for the reporting period. The results for these two activities can be derived from the change in the long and short-term loans over the reporting period, and the change in equity capital (not retained earnings). The payment of a dividend to the shareholders by the company will reduce the cash position and is represented in this section. Therefore, the cash flow as a result of financing activities is given by the following expression *Net cash flow and cash equivalents* - The net cash flow for the reporting period is the sum of the cash flows for the operating, investment and financing activities of the company. The final section on the cash flow statement summarizes the cash position of the company.

Conclusion

The basic financial statements are prepared according to accounting principles and conventions. Two of those that impact on the general understanding of the financial statements are accrual accounting and the historical cost conventions. Accrual accounting recognizes transactions when a company commitment has been made, rather than when the payment is made. This allows for the accurate recording of credit transactions. The financial accounts are prepared on the basis of historical costs, rather than current market values. They represent a true reflection of the transactions at the time at which they occurred. This particularly affects assets, whose book value may have no bearing on its market value or its operational value.

The dual nature of transactions was considered, which lead to an expression known as the accounting equation. The accounting equation is the basis of the balance sheet, and states that the value of the assets of a company is equal to the liabilities plus the owner’s equity.

The business process was considered in the form of a flow diagram with a feedback loop. The construction of the income statement from the business process was discussed. The construction of the balance sheet from the accounting equation was presented, and the derivation of the cash flow statement from the other two statements was discussed. The interaction between the financial statements was derived.

Acknowledgements
This artical is the result of the projects implementation: Project KEGA 009TUKE-4/2020 Transfer of Digitization into Education in the Study Program Business Management and Economics, KEGA 001TUKE-4/2020 Modernizing Industrial Engineering education to Develop Existing Training Program Skills in a Specialized Laboratory.

References

[12] JAKUBCOVÁ, E., VIDOVÁ, J.: Účtovníctvo. SjF TU v Košiciach, Košice 2003, ISBN 80-7099-898-9, 168 s.
[13] KÁDÁROVÁ, J.: Evaluation in the performance management. In: Transfer inovácií. č. 32, 2015, s. 257-260. ISSN 1337-7094.
[14] KÁDÁROVÁ, J.: Investment and financing decision making in the industrial company. Transfer inovácií. Č. 32, 2015, s. 252-256. ISSN 1337-7094.
[15] KÁDÁROVÁ, J.: The Main Resources of the Economic and Financial Informations. In: Transfer inovácií. č. 24, 2012, s. 21-26. ISSN 1337-7094.
[16] MIHOK, J., VIDOVÁ J.: Approach to company performance and efficiency evaluation that integrates modern methodologies. In: Acta Avionica. roč. 8, č. 12, 2006, s. 131-135. ISSN 1335-9479.
[17] RAJNOHA, R., ZÁMEČNÍK, R.: Hodnotenie ekonomickej efektívnosti alternatívnych kalkulačných modelov. In: ControllerNews 3/2005, Contrast Consulting Praha spol. s r.o., září 2005, s. 13-16. ISSN 1214-5149.
[18] TEPLICKÁ, K.: Moderné trendy v manažérskom účtovníctve,“ ES F BERG TU v Košiciach, Košice, 2012. ISBN 978-80-553-0916-3.
[19] VIDOVÁ, J.: Efektívna organizácia spracovania účtovníctva. In: 5. medzinárodná vedecká konferencia, Trendy v systémoch riadenia podnikov, Herľany 2002, ISBN 80-7099-911-X, s. 213-218.

Contact address

doc. Ing. Jaroslava Kádárová, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: jaroslava.kadarova@tuke.sk

Ing. Michaela Košičová, PhD., MBA
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: michaela.kocisova@tuke.sk

Ing. Martin Trebuňa
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: martin.trebuna@student.tuke.sk

Review process
Single-blind peer review process.

PROCESS MANAGEMENT AS AN EFFECTIVE WAY TO TARGET FOR INNOVATIVE COMPANIES

Peter MALEGA

Abstract: This paper deals with process management, which in today´s competitive environment is the effective way to target for companies, especially when they are innovative. This paper is divided into four main sections. First section treats the reasons for introducing innovations Second section is oriented on the process domain and there are facts about types, method of management and general characteristics of processes. Third section deals with process characteristics and connections between process and related tasks. Fourth section is about business process management and process mapping.
Keywords: process, business process management, innovation, company

Introduction

Innovation are very popular nowadays. They are known as a key action for achieving the business climate of the 21st century. All companies have to be innovative, because only in this way they can ensure their operation, competitiveness and thus their future profit. Most companies, especially small and medium enterprises (SME), do not always know that innovation is not exclusively the privilege of high - tech companies, but that every individual, every company, in every industry, can be innovative. It is clear that innovation is a process that can be learned.

There are many new ideas, but only if value is created from these ideas, they become innovation. Innovation is sometimes based on an existing idea, concept or product and its improvement. The company achieves strategic advantages especially when it is a leader of change, the only way to achieve this is to be innovative.

One of the possible ways to improve the success of the company, to produce products of the highest possible quality and as quickly as possible at the lowest cost, is to improve individual processes, i.e. their innovation.

Reasons for introducing innovations

The financial size of every company is strongly dependent on successful innovation. Innovation is a key driver of economic development and brings many benefits. Our life standard is increasing by ideas and discoveries. Innovation alone can help increase safety, improve healthcare, improve product quality, develop environmentally friendly products and reduce environmental damage. Another reason for innovation is the opening of new markets and a share in these markets. Also, innovation, especially of processes, improves the flexibility of production and reduces production costs, which is a very important point for a prosperous company and innovation also leads to improved working conditions for employees. [1]

Today, a rapidly changing world offers companies many challenges and opportunities, and it is innovation that helps them succeed in business. Technologies, competition, the legislative environment, the globalized market and changing customer requirements and expectations create space for formation of innovation. Innovation, with all its benefits, is the driving force of performance. In Fig. 1 are the benefits that innovation brings for company.

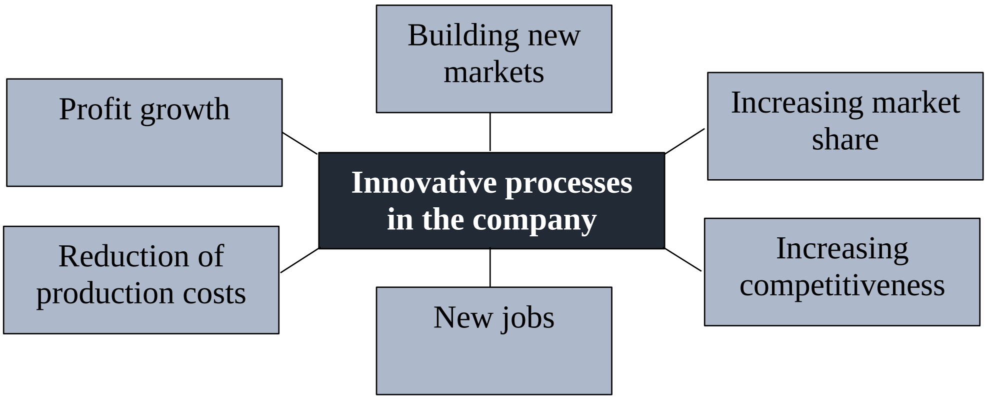


Fig. 1 Benefits of innovation for the company [5]

Process domain

The process domain describes how activities are performed and interconnected. As companies involve a wide range of different processes representing different internal and external activities, a degree of classification has been introduced. The process domain is characterized by primary processes, process behavior, process dependency, and process boundaries.

Primary processes are those processes that primarily involve their participants. These processes are crucial for the creation and delivery of products and services. Processes also have specific behavior such as sequence and conditions. In addition, the processes have a certain range, i.e. boundaries. There is also a dependency between the individual processes, for example such that it is necessary to complete one process in order to be able to perform another process. [2]

The scheme shown in Fig. 2 clearly and simply shows the basic sequence of processes and the transformation of inputs into outputs. In the transformation process, other resources enter the course of the processes, which in the final phase produce output, or the so-called product respectively service for an internal or external customer.

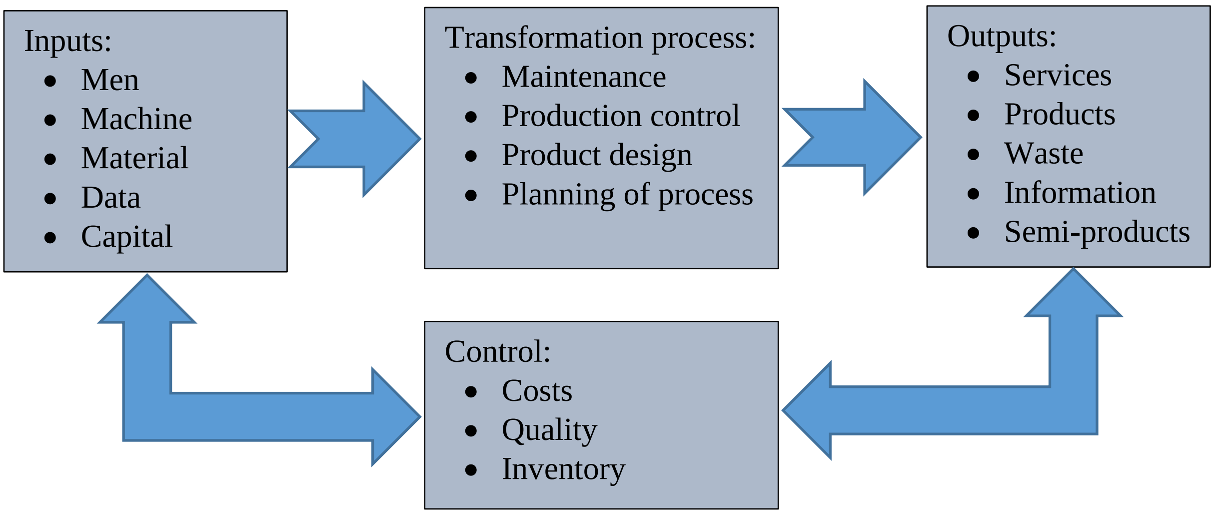


Fig. 2 Process diagram [4]

Depending on the company, industry sector, nature of work, character of processes, process content, structure, frequency of process repetition, purpose or their importance, business processes are divided into different categories. Processes can be categorized into three basic groups:

- Management processes – deal with the measurement, monitoring and control of activities related to business procedures and the system. These processes include internal communication, management, strategic planning, budgeting, management of infrastructure and business performance. Like support processes, management processes do not provide value to customers directly. They create conditions for the functioning of other processes by ensuring the integrity and functioning of the company.
- Primary processes (operational processes) deal with the value chain. These processes bring value to the customer in the form of a product or service. They represent basic business activities and fulfill goals of the company, e.g. generate revenues.
- Secondary processes (support processes) – unlike primary processes, they do not create value for the customer. These processes include accounting, human resource management, workplace safety and others.

In Tab. 1 are types, method of management and general characteristics of processes.

Tab. 1 Types, method of management and general characteristics of processes [3]

Process type	The way to be managed	Process characteristics			
		Does it add value?	Does it run across the organization?	Does it have external customers?	Does it generate sales (profit)?
Primary	performance	YES	YES	YES	YES
Management	cost	NO	YES	NO	NO
Secondary	performance, outsourcing possibility	YES	NO	NO	NO

Process characteristics

There are defined 10 basic process characteristics, which are important for its existence and course. These are the following:

1. Defined process goal and measurable indicators – each process has its own goal, which should be able to achieve. This goal should contribute to the fulfillment of higher goals and the mission of the whole company. In order to monitor how the process succeeds in achieving the set goals, it is necessary to determine equivalent indicators that will evaluate the course of the processes.
2. Process owner – it is a person which is responsible for fulfillment of the process goals, takes responsibility for the course and its long-term operation. If problems occur, it solves them during the process and systematically improves and monitors it.
3. Internal and external customer – the customer of the process represents the subject for which the value is created – the product or service. The subject can be a person, another organization, or the following process. The external customer can be the subject that is outside the company. The internal customer is the subject that belongs to a given organization and uses the outputs of processes as inputs into the process that it performs itself.
4. Inputs – they are used when starting processes. They arise from suppliers or are obtained from the outputs of previous processes. The value is added to the inputs, so each input is transformed into the output.

5. Resources – the basic difference from inputs is that with the help of resources, inputs are transformed into outputs. We can consider material, technologies, human resources, financial resources, information, data, knowledge, documents, applications and time as resources.
6. Outputs – the output of a process is the result that is sold to the customer. The outputs have to be identical to the input to the next process and must have a guarantee of efficiency.
7. Process risks – they have an undesirable impact on the process results and the achievement of goals. These are events, states or actions that have a negative impact on the course or results of the process.
8. Management regulators – these are laws, notices, standards, internal and external directives that are mandatory and should be observed and respected in the process implementation.
9. Set of activities – within the process they are understood as a complete process of work tasks, which are usually performed within one organizational unit and have one measurable product or service at the output, to which one primary source can be assigned. They can be individually – performed by an individual or together – performed by a group of people.
10. Definition of the start, end and overall time process interface – it is important to know all these time data so that its sequence to other processes can be clearly identified.

Processes can be qualified as very rigid (production processes), more flexible (sales) and ad-hoc (the process that can occur during operation).
Processes are usually used as a tool of analysis, optimization and control. During operation, respectively the production, operator performs certain tasks without necessarily concentration on the process as a whole. Process and related tasks are shown in Fig. 3.

Fig. 3 Process and related tasks

The question is how the company can be flexible and at the same time stabile (Fig. 4). To achieve such a balance, the organization have to be "at the border of chaos."

Modern theories follow approaches that take into account the dynamics in companies and markets and thus overcome fixed organizational principles. [7]

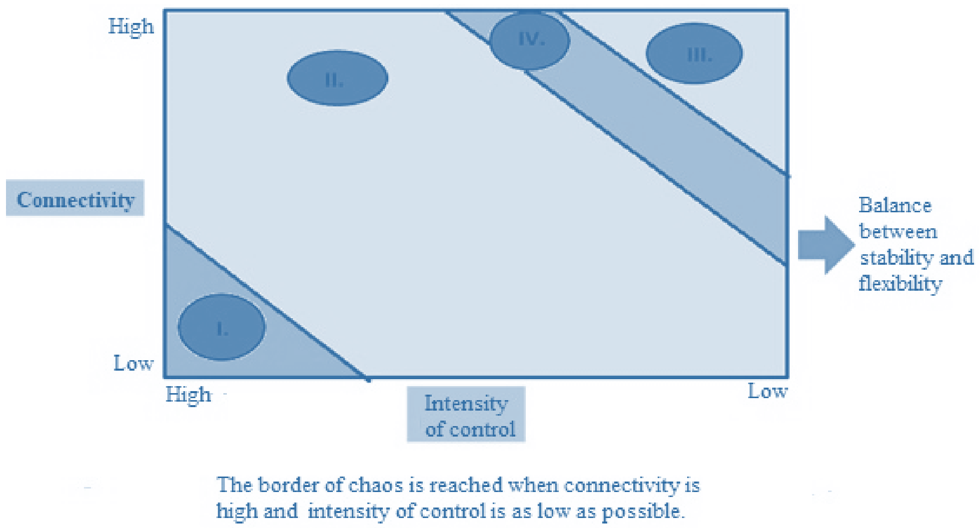


Fig. 4 Balance between stability and flexibility

Business process management and process mapping

Business process management (BPM) is a systematic approach to process improvement, evaluation, measurement and visualization. [2]

The basic characteristic of process management is the ability to respond quickly and flexibly to customer requirements and their fulfillment. If a company is unable to perform some business processes internally due to high costs or lack of resources, the company can use business process outsourcing. [9]

Many companies transfer internal matters such as wages, human resources or accounting to another subjects (third parties).

Following the categorization of processes into management, primary and secondary, it is necessary to relate the processes with three areas [6]:

- Knowledge of processes – every company know its processes, which are performed, as well as its inputs, outputs, resources, but also the way in which inputs are transformed into inputs and the fact, what resources are used in the transformation.
- Verification of activities for the transformation of inputs into outputs – all activities that are part of the process are described and have their parameters. This means that they contain performance characteristics. Therefore, it is important that all participants in the process have to know its role in the transformation of inputs into outputs.
- Monitoring, measurement and continuous improvement – people responsible for the process (usually managers) have data about the efficiency and effectiveness of the processes. Based on the data and indicators, they then propose and modify changes in order to their optimization.

To measure the success of business processes, the organization monitors the successful completion of individual activities within the process, by benchmarking or monitoring the end point of the process. If business processes do not help the company achieve its goal on time or with available resources, there are several strategies for improving those processes. One of these strategies is the business processes mapping**.** [8]

Using process mapping, we can clearly identify how it works in the company. The goal of process mapping is a clear representation of individual processes using a map. The process map is used for simplified decision-making by managers and management of the system and its processes. A well-designed map can help identify weaknesses in the company. The process map must be so clear and truthful that the following points must be clear at a glance:

- what processes take place in the company,
- how the processes are divided,
- who takes responsibility for the processes,
- which processes are connected or interconnected,
- what the company deals with and in which professional area it operates,
- how clearly the inputs, outputs, sources and other parameters are defined.

Conclusion

In today's world, the innovative ability of the company is very important and necessary for the production company, whether in terms of technological development, competitiveness, adaptation to customer requirements or globalization. Thus, innovation is represented by all new ideas that are implemented in the company and help to achieve business goals more effectively.

By innovating processes, the company achieves a significantly improved way of production or certain processes, which means, for example, that it increases productivity, efficiency, reduces costs and many other benefits that help the successful progress of the company.

This article was created by implementation of the grant project KEGA 009TUKE-4/2020 Transfer of Digitization into Education in the Study Program Business Management and Economics.

References

[1] AFUAH, A.: Innovation Management: Strategies, Implementation, and Profits. New York: Oxford University Press. 1998.

[2] BRABANBER, E, DAVIS, R,.: ARIS Design Platform Getting Started with BPM, Springer, 2007.

[3] DRAHOTSKÝ, I. – ŘEZNÍČEK, B.: Logistics – processes and their management. Brno: Computer Press, 2003. 344 p. ISBN 80-7226-521-0.

[4] GRASSEROVÁ, M., et al.: Process management in the public and private sector. 1st Edit. Compter Press a.s. 2008. 266 p. ISBN 978-80-251-1987-7.

[5] HAOUR, G.: Resolving the Innovation Paradox – Enhancing Growth in Technology Companies. Palgrave Macmillan. 2004.

[6] INDULSKA, M., KITTEL, K., MUEHLEN, M.: Towards Integrated Modeling of Business Processes and Business Rules, 2008.

[7] ŘEPA V.: Business processes: process management and modeling. 2nd updated and expanded edition, Praha: Grada Publishing, 2007. 281 p. ISBN 978-8024-7225-2-8.

[8] ŠMÍDA, F.: Implementation and development of process management in the company, 1st Edit. Grada Publishing, 2007. 293 p. ISBN 978-80-247-1679-4.

[9] ZÁVADSKÝ, J.: Business process performance management. Zvolen: Matej Bel University, 2005. 120 s. ISBN 80-8083-077-0.

Contact address
Ing. Peter Malega, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
E-mail: peter.malega@tuke.sk

Review process
Single-blind peer review process.

ANALYTICAL COMPARISON OF ELECTRIC AND CONVENTIONAL ENGINES

Laura LACHVAJDEROVÁ – Jaroslava KÁDÁROVÁ

Abstract: The main purpose of this article is to compare a conventional engine with an electric one. It is a statistical analysis performed on the basis of numerical data from the manufacturers of individual vehicles models. The study also focuses on the development of vehicles sales over the last 10 years in the European Union. Based on simple numerical calculations, the output is the evaluation and comparison of selected models in the form of graphs. The article answers the question of whether it is possible to fully replace a conventional engine with an electric one on the basis of facts obtained.
Keywords: electromobility, alternative propulsions, statistical analysis

Introduction

Mobility has still been, remains a basic human need and will continue to make a significant contribution to a standard of living motivated by the need for the rapid and individual transport of goods and people. The uncontrollable increase in the number of cars is causing problems today, whether it is parking, traffic jams or, last but not least, environmental pollution. The vast majority of today's cars use an internal combustion engine, either petrol or diesel. It is these engines that cause air pollution and, in large cities where there are significantly more cars, burden human health by creating smog. This is one of the reasons why electric motors used in electric vehicles (EVs) could replace internal combustion engines. It is this alternative that is supposed to bring an ecological solution to the world and finally stop the enormous increase in emissions from transport.

The topicality of this subject calls for attention in every sector, whether from the point of view of the environment, the economy or global technological development. Every day, the world welcomes news in the world of electromobility and it is only a matter of time before the EV overtakes its conventional rival. However, with so many positive reports, the question arises as to whether an EV is a practical choice for every type of user. There are several factors that affect the practicality of an EV. It is about the comfort of the passenger, the possibility of refueling, resp. energy but especially the total range. Logically, these are factors that significantly affect the purchase of each means of transport.

Vehicles powered by an electric motor can be found in all possible variations, from electric bicycles and scooters, through EVs to electric buses. The most numerous group of means of transport consists of passenger EVs. Electromobility can also be characterized as a road transport system that is based on EVs. The relevant differences between electrical and conventional technology concern the basic components of the system - a rechargeable battery used to store energy and an electric motor that transforms electricity into a driving force. Some of these vehicles are equipped with technologies that enable them to generate their own electricity (e.g. hybrids or plug-in hybrids). Others use energy that is supplied from a source of electricity outside the vehicle - usually from the electrical system. [1] As the vast majority of people are used to the fact that the range of a regular vehicle is just over 500 km per refueling, it is difficult to persuade someone to choose a greener option when buying a new vehicle, of course in many cases more expensive, with a maximum quarter of the range. Mainly, for this reason, it is very important to increase the maximum range of the EV, as well as to build a network of charging stations, which should be similarly heavy as the network of filling stations.

From a political point of view, EVs are promoted by various subsidy programs or even tax breaks. At the end of 2019, the registration of potential applicants for an EV took place in the Slovak Republic. The Ministry of Economy of the Slovak Republic thus supported the development of electromobility by offering a subsidy in the total amount of 6 million euros for buyers of EVs. This money was redistributed in a record 3 minutes and 41 seconds among 668 applicants who applied for a subsidy for 786 EVs. Of this, 12.5% of registrations were applications for subsidies for the plug-in hybrid and 87.5% belonged to pure electric propulsion. It is clear from this that interest in the electric car in Slovakia is high, but funding is still limited. Just out of curiosity, if the subsidies were redistributed among the people in the first 40 minutes, the state would need about 25 million euros. The total subsidy for an electric car with a hybrid drive is EUR 5,000 per applicant, provided that the subsidy applies only to new vehicles purchased in the Slovak Republic and the limit for the purchase of a vehicle is up to EUR 50,000, VAT included. For pure EV, the amount is a little higher, EUR 8,000 with the same conditions. [2]

Electromobility

The modern history of electromobility dates back to 2010 when the first models of EVs began to be mass-produced. Since then, the infrastructure of charging stations has been built and new models have been launched. The gradual advent of technology may seem like a problem, but that does not make it as close as the caution and hesitation of retailers and manufacturers to what the competition is likely to do. With the arrival of models with a range of up to 400 km, there was an adequate and sufficient replacement for internal combustion engines. With the growing demand for EVs, the quality infrastructure of charging stations also grew, without which the electric car would not be able to function. Another option that was supposed to serve the customer as a sufficient replacement for a vehicle with an internal combustion engine is the plug-in-hybrid. The vast majority of these vehicles can be registered on the market in the last four years. The offer of this variant can be found today in the catalogue of every car company. [3] In the graph below (Fig. 1) we can see the percentage of sales of gasoline, diesel and electric engines in the years 2010 - 2019. The number of registered EVs, including hybrids and plug-in hybrids, is growing every year. The sale of petrol vehicles has been the best since 2014 when the demand for this type of drive is rising every year. In 2019 alone, they accounted for 59% of registered vehicles worldwide. On the contrary, sales of diesel engines are declining mainly due to declining supply of vehicles, which are governed by EU emission standards. It seems that the classic petrol engine is far from over. [4]

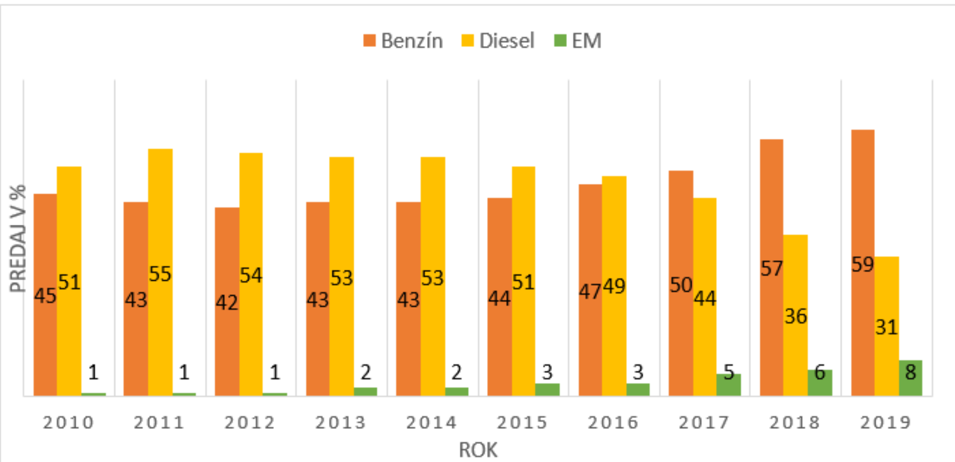


Fig. 1 Vehicles sales by engine type in recent years [4]

Statistical analysis

From the manufacturer's point of view, it is important to focus on reducing emissions, from the user's point of view, the overall range, time and financial costs become a priority. In order for EVs to function as a full-fledged means of transport, the driver should not consider whether has to be a plan of stops before a long journey and calculate how many times the EV will have to be recharged. This is one of the reasons why various alternative propulsions are being introduced to meet the expectations of every driver.

The subject of the next part will be the simulation of statistical analysis, where it will be a selection of three mutually different propulsions. Three types of vehicles will be presented on a predetermined route under ideal conditions, i. j. in smooth road traffic without unexpected traffic restrictions, in sunny weather (15 ° C). The vehicle types will be a battery electric vehicle (BEV) and an internal combustion engine vehicle (ICEV), in this case, a petrol engine type. Both vehicles are in the same price category - € 65,000 to € 75,000. The parameters on which this experiment focuses are the engine powers that are decisive for the simulation and the maximum speeds. The output will be the evaluation and observation of three factors:

- Total costs
- Total range to the full tank/battery
- Total time spent on the road

From the customer's point of view, these factors are among the key, resp. the customer also makes a decision based on this information. The simulation, based on simple statistical calculations, will help to specify the ability of the EV to match the conventional rival.

It was necessary to plan a variety, resp. a combined road that would include both municipalities and 1st and 2nd class district roads when the road was chosen with regard to the evaluation of selected vehicles in the given categories. This is due to the fact that the so-called combined consumption (average consumption that the car achieves when it changes speeds up to 50 km/h and above 50 km/ h). The total length of the road is 860 km. The starting point, the place from which the vehicle starts, is located in Bratislava. The second point is Lučenec, next Prešov and Ružomberok. From Ružomberok, the vehicles are moved back to Bratislava, which is also the destination of the specified route (Fig.2). For objectivity in both categories, the chosen road avoids all paid sections, as this could affect the price per kilometer. Therefore, the highway will not be considered in this analysis. The current infrastructure of the charging stations on the selected road is sufficient and does not represent any major restrictions for the driver of the EV.

Fig. 2 Map of the selected road [5]

Evaluation of factors

The first model to be evaluated on this road is the Mercedes-Benz EQC 400. It is a pure electric vehicle (BEV). The engine power of the electric car is 300 kW and the battery capacity is 80 kWh. Based on these values, the manufacturer states the consumption of 25 kWh/100 km. The combined range is 300 km. Emissions emitted when using an electric car are zero, i. j. 0 g CO_2/1 km. The following calculations determine how many times EV will have to recharge the battery for a given road to reach its destination. The calculations will take into account the price for recharging at the fast-charging stations of the company ZSE (West Slovak energy), which represents 0.39 €/kWh, that means 9.75 €/100 km, thus 0.0975 €/1 km. For clearer calculations, this amount is rounded up to 0.10 euros per 1 km. The first evaluated factor will be the total cost of the route, resp. the price for the fuel/electricity needed to complete the route. The average price for recharging at a distance of 100 km, according to data obtained on the ZSE website, is € 9.75. From this information, the output is therefore the amount that is the fuel cost for the specified route. As the battery charge per 1 km, according to data from ZSE, means 0.10 € and the length of the route is 860 km, the final amount in the case of BEV is statistically 86 €. This means that the EV will have to recharge the battery 2.7 times on the selected route. The maximum range of a fully charged battery, based on battery capacity (80 kWh) and its combined consumption per 100 km (25 kWh), is 320 km. The analysis counts with an average speed of 70 km/h (an average of maximum speeds inside and outside the village). According to this statement, both types of vehicles should cross the 860 km route in 12.3 hours (738 minutes). In the case of BEV, battery charging should be considered, in particular from 0 to 100%, it represents approximately 1 hour and 30 minutes (90 min). Therefore, the time for which this vehicle travels a given distance is extended by 4 hours (243 min). The total time spent on the route by the EV is 16.4 hours (981 min).

The second model to be analyzed is the Jaguar F-Pace, powered by a petrol engine. Under the hood is an engine with an output of 300 kW. The capacity of the fuel tank is 82 liters, which with a combined consumption (municipality/outside the municipality) of 8 l/100 km represents a range of 1025 km. The calculation of the total cost of the route is based on the average price of gasoline for 2019, which is 1.334 € per 1 liter. The average price of petrol per 1 km for combined consumption after rounding is 0.11 € / 1 km. It follows that the total price of fuel and at the same time the total cost of the 860 km long route is € 94.6. In terms of time, the car does not have to stop at the gas station. Due to its combined consumption and range, the vehicle will suffice. The total time for this type of vehicle is 12.3 hours.

Tab. 1 Results of statistical analysis

	BEV	**ICEV**
Total costs (€)	86	94,6
Total range to the full tank/battery (km)	320	1025
Total time spent on the road (h)	16,4	12,3

The total costs for selected models vary with respect to consumption and drive type. The analysis focused only on fuel, but there are many more factors that affect the overall cost of driving: tire wear, maintenance, fines, unexpected travel expenses and much more. The plan of this analysis, however, was to focus only on fuel under ideal conditions throughout the journey, resp. the lapse of the route would be smooth and without incidental expenses. Calculations have shown that an electric car pays € 0.10 per 1 km of energy consumed. At first glance, this amount seems ridiculous, but after a sharp increase in the price of charging, the possibility of using only an EV appears as a nightmare for a person with an average Slovak salary. People would expect that in the case of a gasoline internal combustion engine, the amount for the total cost will be horrible, but this is not this case (Fig. 3).

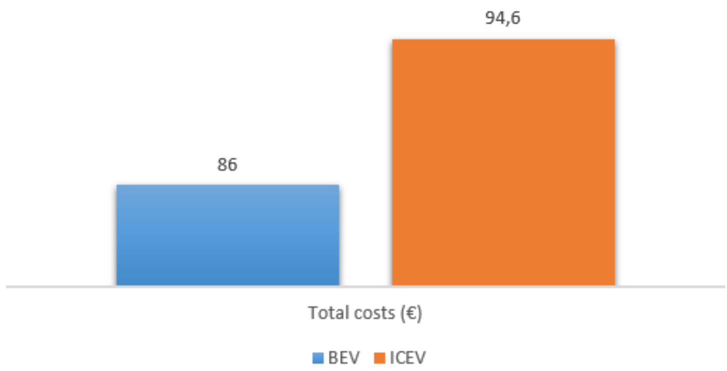


Fig. 3 Comparison of total costs

As with the economic factor, we must not forget the factors that affect **the total range** of the vehicle. Both models have different propulsions and consumption, which are key to the overall range. In the case of an EV, it is an electric motor with a battery, which has the appropriate capacity and which affects the range of the vehicle itself. Of course, we must not forget the fact that the total battery consumption depends on the outside air temperature but also on the driving style, so this analysis had ideal conditions, i. j. an average speed of 70 km / h, when the total range of the electric car is most ideal and the outside air temperature would be around 15 ° C, which means that the battery is not discharged due to the heating or air conditioning. ICEV will have a maximum range under combined conditions under ideal conditions, which fits our analysis favorably (Fig. 4).

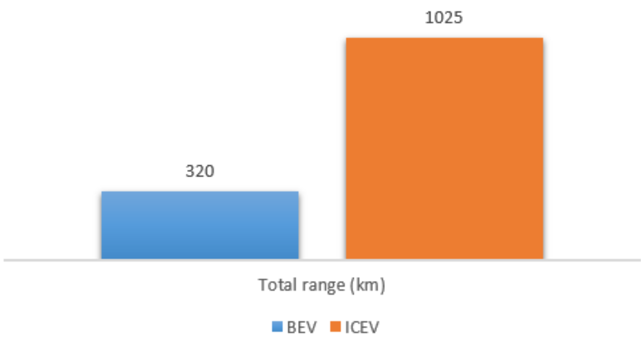


Fig. 4 Comparison of the total range

An interesting criterion is **total time**. Interesting because in today's modern age is full of hurried people, it is, unfortunately, true that time means money. In other words, in the shortest possible time, people want to either save the most or earn the most. To explain this factor in more detail in a given analysis, the following example explains. A certain courier must deliver the shipment to a certain place. It will be important for both the customer and the employer to deliver the shipment as soon as possible. From the customer's point of view, the reason is simple, it is mainly about impatience and the anticipated need for the ordered goods. The reason from the employer's point of view is certainly satisfaction, good feedback and evaluation of customer services in case the shipment is delivered in the shortest possible time, but the main reason on the part of the employer is to save the most time from which the total courier salary is derived. It is therefore clear from this example that time plays a major role today. In figure 5 it can be seen that the EV, with the necessary need to recharge the battery 2.7 times during the entire route, would certainly not please any owner of the courier company. The ICEV fulfil what was expected from the beginning - the fastest way to finish the planned route. In terms of time, a vehicle with an internal combustion engine is most suitable.

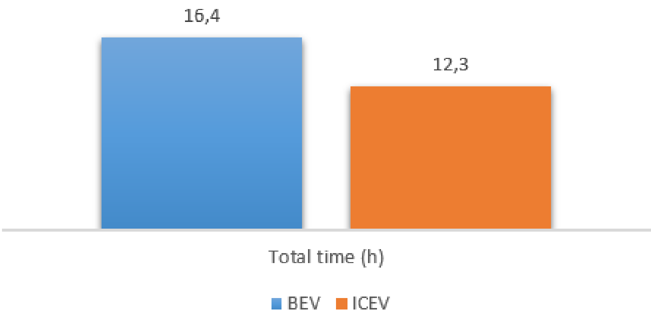


Fig. 5 Comparison of the total time spent on the route

Conclusion

In the case of simulated statistical analysis, this is an ideal case that a person would find very difficult to encounter in everyday life. It should be mentioned that errors and uncertainties arise mainly due to the fact that the problem has adapted to the least expected course of the route. Few people adhere to a precise speed in and out of municipalities, so the average speed in real life would be certainly higher than 70 km/h. As for the condition of the planned route, it is unnecessary to argue that it will be as ideal as presented in the design and that the vehicle would not suffer any technical failure. Also unexpected traffic restrictions, construction/repair of roads, which would significantly affect the total time of the route. As the average speed increases, so do consumption, and thus the expected range decreases. For example, in the case of an EV, the total consumption increases only when the weather changes, that is why analysis designed 15 ° C, which guaranteed us the lowest energy consumption from the battery. The guarantee of good weather is never one hundred percent.
The output of this simulation is an opinion where none of the options can be assessed as the best in general. BEV alone is clearly not the best choice for the impatient resp. time-limited people who need to move from point A to point B in the shortest possible time. On the contrary, ICEV guarantees a fast, in terms of range, safe, a little more expensive range to the finish destination. There are many more factors that influence the choice of a particular type of propulsion. Emissions from transport are one of the possible factors. It is well known that during the use stage of BEVs, the vehicle does not emit any emissions and ICEV probably eliminates them way too much. This is how you can go ahead and look for the pros and cons of each propulsion. Based on the evaluation, everyone can form their own opinion and choose the best option, which means that the BEV would be able to fulfil the expectations of each driver, only to the extent that the driver's demands allow.

This document has been prepared in support of a grant project APVV-19-0418 Intelligent solutions for increasing the innovative capacity of companies in the process of their transformation into intelligent companies.

References

[1] EUROPEAN ENVIRONMENT AGENCY: Electric vehicles in Europe. In: EEA Report. No. 20 (2016), ISSN 1977-8449, pp. 41-45.
[2] HALUŠ, Martin – ENGEĽ, Marek. 2019. The electric propulsion gradually gets green. In: Institute of Environmental Policy, Minzp [online]. [quoted on October 2, 2020]. Available at: https://www.minzp.sk/files/iep/2019_4_elektricky_pohon_dostava_postupne_zelenu.pdf.
[3] LACHVAJDEROVÁ, Laura. 2020. Electromobility as part of the transition strategy to emission-free forms of transport. Diploma thesis. [quoted on September 30, 2020].
[4] ŠVANČARA, Michal. 2020. The year 2019: Record car sales in Slovakia. The share of diesel cars in Europe has fallen again [online]. [quoted on October 1, 2020]. Available at: https://www.auto.sk/zivot-vodica/rok-2019-rekordny-predaj-aut-na-slovensku-podiel-naftovych-aut-v-europe-opat-klesol.
[5] MAPY.CZ, 2020 Mapy.cz [online]. [quoted on October 2, 2020]. Available at: https://sk.mapy.cz.

Contact address

Ing. Laura Lachvajderová
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: laura.lachvajderova@tuke.sk

Review process

Single-blind peer review process.

APPLICATION OF DEVIATION ANALYSIS METHODS IN INVESTMENT MANAGEMENT

Jaroslava JANEKOVA – Jana FABIANOVA - Daniela ONOFREJOVA

Abstract: The article presents a case study, where the method of Deviation analysis is applied in the utilisation phase of the assessed investment project. Conducted analysis of deviations is supplemented by specifying the causes of deviations and taking measures leading to a reduction in the probability of their occurrence.
Keywords: Investment, deviation analysis, cash flow, Net Present Value.

Introduction

Due to the specification of the expected financial results of the investment project it is necessary to analyze currently achieved economic results with planned results, even in the phase of its implementation. Conducted analysis of deviations must be accompanied by finding the causes of deviations or accountability for deviations, and measures leading to a reduction in the probability of their occurrence.

Case study description and problem definition

The object of the study is the investment project "Reprographic Centre." Its mission is to provide comprehensive, high quality, fast and principally cheaper copying services than competing facilities. The Centre is located near the university, in areas that had long been unused. For its service, it was necessary to invest in new equipment required for the performance of services. The most significant cost items consist of two powerful copy machines and furniture with a service desk in a total value of EUR 10,000. Remaining devices have been purchased but were not used before.

The aim of this paper is to measure the deviations of cash flow actually achieved from operating activities against the planned cash flow, with emphasis on the planned EBITDA indicator, from the first year of operation of the project. Moreover, in case of significant negative deviations propose measures for their elimination in the coming years of the economic life of the investment project.

Materials and methodology

Economic evaluation of the investment project. The evaluation is realized by the financial criteria Net Present Value (NPV) for the economic life of four years (1).

$$NPV = \sum_{n=1}^{N} \frac{CF_n}{(1+i)^n} - IC \qquad (1)$$

Where: *CFn* is cash flow in year n, *IC* investment costs, *N* economic life of the investment, *n* number of years of economic life of the investment and *i* discount rate.

The NPV indicator value is determined by the amount of annual cash flow from the investment, and value of one-time investment costs. Substantial impact on the NPV has an indicator CF, thus generally for investments only cash flow from operating activities is considered. Impact of funding investment is taken into account when discounted at a discount rate that includes a risk of the owner, including the risk of creditors. Relationship for predicting annual CF from operating activities can be expressed, as follows:

$$CF = EBIT \cdot (1-t) + D - \Delta NCWC \tag{2}$$

$$CF = (EBITDA - D) \cdot (1-t) + D - \Delta NCWC \tag{3}$$

$$EBITDA = p_1 \cdot P_1 + p_2 \cdot P_2 - c_{variable1} \cdot P_1 - c_{variable2} \cdot P_2 - C_{fixed} \tag{4}$$

Where:*EBIT* is Earning Before Interest and Tax, *EBITDA* Earning Before Interest, Tax, Depreciation and Amortization, *D* depreciation, *t* income tax rate, *NCWC* Non Cash Working Capital, *p* price, *P* production, $c_{variable}$ variable costs and C_{fixed} fixed costs.

EBITDA height can be influenced solely by manufacturing and sales activities, what confirms its calculation method of (4). In the calculation it is considered that the object of production is characterised by two types of printing paper (1 - color print, size A4, 2 - black-and-white print, size A4) sold at different prices. Input variables for the case study were scheduled based on demand for the services the Centre provides.

Deviation analysis. Deviation means the difference between the two values of the monitored variables. They can be monitored on a comparison of fact – fact, plan - fact and plan-expectations (Scholleova, 2009). Just deviations in plan - expectations are the subject of this study. This forecasts the delays in implementing the plan. Expectations already include the effect of the measures as a result of last evaluation plan - fact. This comparison is focused on the future and respects the principle of ex-ante evaluation.

Procedure of Deviation Analysis. The application of this method is carried out in three steps:

1. *Selection of a synthetic indicator and its pyramidal decomposition* (Figure 1). Among the indicators of pyramidal decomposition there are logical links, expressed by simple mathematical operations and mutual conditioning, which means that the indicator of a lower degree is an economic criteria for indicator of a higher degree.

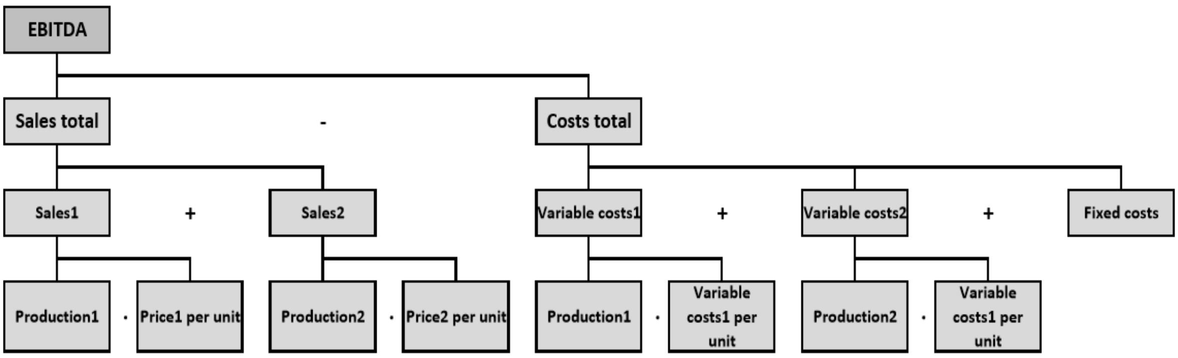


Fig. 1 Pyramidal decomposition of the EBITDA indicator

2. *Quantification of the impacts of different analytical parameters to change in the synthetic indicator.* The calculation algorithm depends on the type of linkage among analytical indicators whose effects are calculated. Input data for the calculation of the synthetic

indicator X, whose value in this case is determined by two analytical indicators and A, B. The expected value of the indicators are X_0, A_0, B_0,, actual values X_1, A_1, B_1.
Effects of changes in the analytical parameters on change in the synthetic indicator X at additive binding can be quantified, as follows:

Absolute deviation X:

$$\Delta X = X_1 - X_0 = (A_1 + B_1) - (A_0 + B_0) = (A_1 - A_0) - (B_1 - B_0) = \Delta A + \Delta B \tag{5}$$

Relative deviation of percentage change in X:

$$\Delta X = \frac{X_1 - X_0}{X_0} = \frac{\Delta A + \Delta B}{X_0} = \frac{\Delta A}{X_0} + \frac{\Delta B}{X_0} \tag{6}$$

Relative deviation on total change in X in percent:

$$(I_X - 1) \cdot 100 = \frac{\Delta A}{\Delta X} \cdot (I_X - 1) \cdot 100 + \frac{\Delta B}{\Delta X} \cdot (I_X - 1) \cdot 100 \tag{7}$$

For binding has the method of calculating the effects the same concept as previous one, except the fact, that the indicator B is deducted from A by minus sign.

Effects of changes in the analytical parameters on change in the synthetic indicator for multiplicative binding can be quantified by several methods. This contribution applies the *logarithmic method*, which is based on the logarithmic indicator index scaling. Effect of changes in analytical indicators on change in the synthetic indicator X for binding is quantified as follows:

Absolute expression of impact:

$$\Delta X = \frac{\log I_A}{\log I_X} \cdot \Delta X + \frac{\log I_B}{\log I_X} \cdot \Delta X \tag{8}$$

Relative expression of impact:

$$(I_X - 1) \cdot 100 = \frac{\log I_A}{\log I_X} \cdot (I_X - 1) \cdot 100 + \frac{\log I_B}{\log I_X} \cdot (I_X - 1) \cdot 100 \tag{9}$$

For binding has the method of calculating the effects the same concept as previous one, except the fact, that the indicator B is deducted from A by minus sign.

3. *Evaluation of deviation and corrective action*. After quantifying the deviations, the causes must be found, and the measures taken, in order to significantly reduce the probability of such deviations in the future.

Results

The method of Deviation analysis is implemented on the investment project of the "Reprographic Centre". The project is economically evaluated using the indicator NPV, and its value is expected to EUR 17,493 for the period of four years. The most important factor that influences the resulting NPV is CF from operating activities. Due to the fact that a depreciation and rate of income tax have on CF from operating activities generally zero, respectively minimal impact, the Deviation analysis focuses only on the EBITDA indicator, which is calculated according to equation (4). It is accmplished by a pyramid decomposition of the EBITDA indicator, shown in Figure 1. The challenge is to identify which variables have the strongest impact and positively or negatively affect the decline in actual results compared with EBITDA projected value after the first year of the operation of the project. Input data for the calculation of the deviations are shown in Table 1. For each monitored indicator, three variations are quantified. The calculation procedure is determined by binding among analytical indicators. The values of calculated deviations are shown in the chart in Figure 2 in following order starting from absolute deviation, relative deviation of percentage changes in the synthetic indicator and the relative deviation in the total change of the synthetic indicator.

Table 1 The values of variables and changes that are part of the pyramid model EBITDA

Indicator	Plan for 1st year	Actual for 1st year	Absolute change	Relative change	Index changes
1	*2*	*3*	*3-2*	*[(3-2)/2]*	*(3/2)*
Production1	15,000	13,245	-1,755	-0.1170	0.8830
Production2	100,000	104,258	4,258	0.0426	1.0426
Price1 per unit	0.30	0.25	-0.05	-0.1667	0.8333
Price2 per unit	0.05	0.05	0.00	0.0000	0.0000
Variable costs1 per unit	0.03	0.0287	-0.0013	-0.0433	0.9567
Variable costs2 per unit	0.005	0.0068	0.0018	0.3600	1.3600
Fixed costs	700	630.46	-69.54	-0.0993	0.9007
Sales1	4,500	3,311.25	-1,188.75	-0.2642	0.7358
Sales2	5,000	5,212.90	212.90	0.0426	1.0426
Sales total	9,500	8,524.15	-975.85	-0.1027	0.8973
Variable costs1	450	380.13	-69.87	-0.1553	0.8447
Variable costs2	500	708.95	208.95	0.4179	1.4179
Variable costs	950	1,089.09	139.09	0.1464	1.1464
Costs total	1,650	1,719.55	69.55	0.0421	1.0421
EBITDA	**7,850**	**6,804.60**	**-1,045.40**	**-0.1332**	**0.8668**

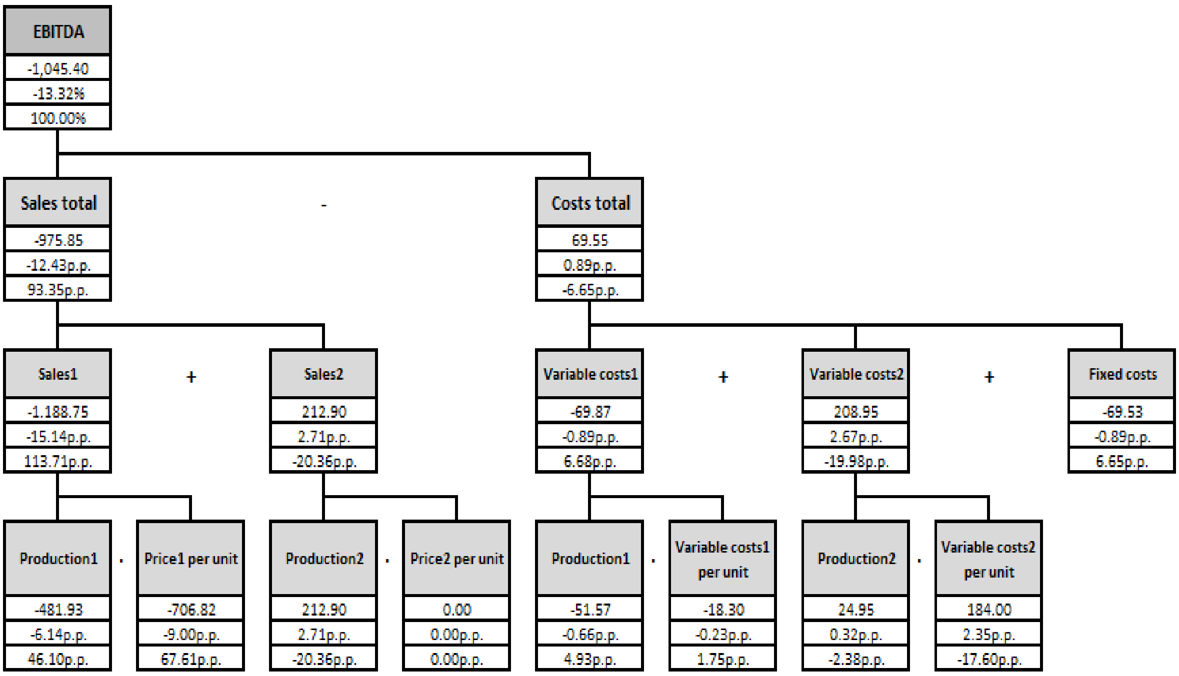


Figure 2 Decomposition values of the pyramid model EBITDA

Evaluation of deviations. The total deviation of EBITDA indicator is negative. Its value in the first year of operation decreased by 13.32 % against the planned investment. This decline is due to the decrease in revenues (sales total) by 12.43 percentage points and increased costs (costs total) by 0.89 percentage points.

Decline in total sales was negatively affected by revenues from the sale of color printing (sales1) by 15.14 percentage points and positively by increase in revenues from sales of black and white printing (sales2) by 2.71 percentage points. Most problematic areas include the price of color printing format A4, which decreased by 16.67 % but the impact on the overall deviation is 61.67 percentage points and a decrease in sales volume of color printing format A4 of 11.70 % with an impact on the overall deviation of 46.10 percentage points. Increase in costs total was caused by negative increase in variable costs for black and white printing (variable costs2 per unit) of 36.00 % with an impact on the overall deviation of 19.98 percentage points. Positive impact on total costs had both, variable costs 1 and fixed costs.

Draft measures. The anomalies and their causes form the basis for decisions on management of investment projects in the coming years of its economic life. The problem can be solved in several ways. Here, two variants are analyzed. The first variant considers the cost of color printing A4 format in actual amount of EUR 0.25 while maintaining the originally planned production. The second alternative solution considers the increase in the price of color printing A4 format from EUR 0.25 on the originally planned price of EUR 0.30, while reducing the originally planned production by 9 %. For comparison of benefiting from the solutions proposed, the expected values of the NPV are shown in Table 2.

Table 2 The NPV values

Variant	NPV_{Plan}	NPV_{Actual}	$NPV_{1.variant}$	$NPV_{2.variant}$
NPV in EUR	17,493	16,752	14,989	15,800
Absolut change from NPV_{Plan} in EUR	-	-741	-2,504	-1,693
Relative change from NPV_{Plan} in %	-	-4.24	-14.31	-9.68

Market reaction to the price of color printing can be positive or negative, that’s the reason why it is appropriate to apply the method of Deviation analysis even after the second year of life of the investment, and thus to assess the investment according to current information. Such approach just confirms the nature of the Deviation analysis that is understood as a continuous, systematic, repeated and never-ending process.

Conclusion

Investment project management in practice mainly focuses on the preparation and implementation of a phase of investment. During the use of investment, a management of deviations in the planned indicators’ values (e.g. CF or costs) is often neglected, but no less important to the overall success of the investment project. Early identification of the sources and causes of deviations creates an opportunity for implementing appropriate measures in order to eliminate or compensate for the differences and achieving the intended project outcomes.

The presented case study highlighted the importance and possibilities of ex-post analysis of the investment project as part of project management. An illustration of the Deviation analysis demonstrated on the EBITDA indicator may remain as a model for similar analysis, and after appropriate modifications is applicable anywhere in the corporate practice.

Acknowledgment
This work has been supported by the APVV-19-0418 Intelligent solutions for increasing the innovative capacity of companies in the process of their transformation into intelligent companies.

References
[1] JANEKOVÁ, J. et al.: Implementation of deviation analysis method in the utilisation phase of the investment project: a case study. 2017. In: Polish Journal of Management Studies. Vol. 15, no. 1 (2017), p. 99-109. - ISSN 2081-7452
[2] KOTULIČ, R., KIRÁLY, P., RAJČÁNIOVÁ, M.: Finančná analýza podniku. 2. Vyd. Bratislava: Iura Edition, spol. s r.o., 2010, s. 238. ISBN 978-80-8078-342-6.
[3] SHOLLEOVÁ, H.: Investiční controlling. Jak hodnotit investiční záměry a řídit podnikové investície. 1. vyd. Praha: Grada Publishing, a.s. 2009, s. 288. ISBN 978-80-247-2952-7.

Contact address
Ing. Jaroslava Janeková, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: jaroslava.janekova@tuke.sk

doc. Ing. Jana Fabianová, PhD.
Technical University of Kosice, Faculty of Mining, Ecology, Process Control and Geotechnology, Letná 9, Košice, Slovakia
e-mail: jana.fabianova@tuke.sk

Ing. Daniela Onofrejová, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: daniela.onofrejova@tuke.sk

Review process
Single-blind peer review process.

CAR PRODUCTION AS A CORE COMPONENT IN THE ECONOMY OF THE SLOVAK REPUBLIC

Peter MALEGA

Abstract: This paper deals car production in the Slovak republic, which is strongly affected with pandemic Covid-19. Automotive industry in Slovakia is the key element, because it is about 50% of overall industry in Slovakia for several years. Components and material composition of the car is therefore in the centre of the attention of many studies that is oriented on the Slovak economy. Current situation in automotive industry is very hard, but for the clever automotive producers is also the possibility to rise and to bring new innovation for customers.
Keywords: car, production process, Slovak republic, automotive industry, Covid-19

Introduction

The development of innovations in the field of digitization and automation of production processes is constantly proceed. Today, the processing of these tools is at a high level, which greatly helps in production processes planning. [6, 7]
Car production in Slovakia increased slightly in 2019 and set a record. In total, more than 1.1 million cars were produced, compared to 1.09 million in 2018. Slovakia thus maintained its position as a world No. 1 in car production per capita.
The automotive industry is still the main driver of the Slovak economy. The share of the automotive industry in the performance of industry reached 49.5% in 2018.
In connection with the spread of the deadly coronavirus Covid-19, the risk of decreasing of the entire automotive industry (not only in Slovakia) also increased significantly. According to experts, the negative effects on the Central European economies (including the Slovak economy) will be significant.
As in 2019 the automotive industry faced many challenges and obstacles. It was caused, because of the overall slowdown in the global economy. Car sales in major world markets decreased. Several experts from insurance companies expect that by the end of 2020, the production of this sector worldwide will start to decrease by about 75%.
Despite the current problems, automotive industry in Slovakia is expected to remain a priority sector in next years.

Components and material composition of the car

Today's modern cars achieve high quality in terms of safety, quality, passenger comfort, but high emphasis is also placed on the car's construction, which affects its look and other properties, such as aerodynamics. In Fig. 1 we can see an overview of the components of today's modern middle class car, which today consists of about 9000 parts. [2, 3]

Development in the field of automobiles today is constantly going ahead, and this is also the fact in the production processes in the automotive production. [1] Today, the car is a complex structural unit made up of a wide range of materials to achieve the best possible construction properties in terms of strength, durability and lifetime. In Fig. 2 is an overview of the materials used for the production of a conventional middle-class passenger car in percentage. [4, 8]

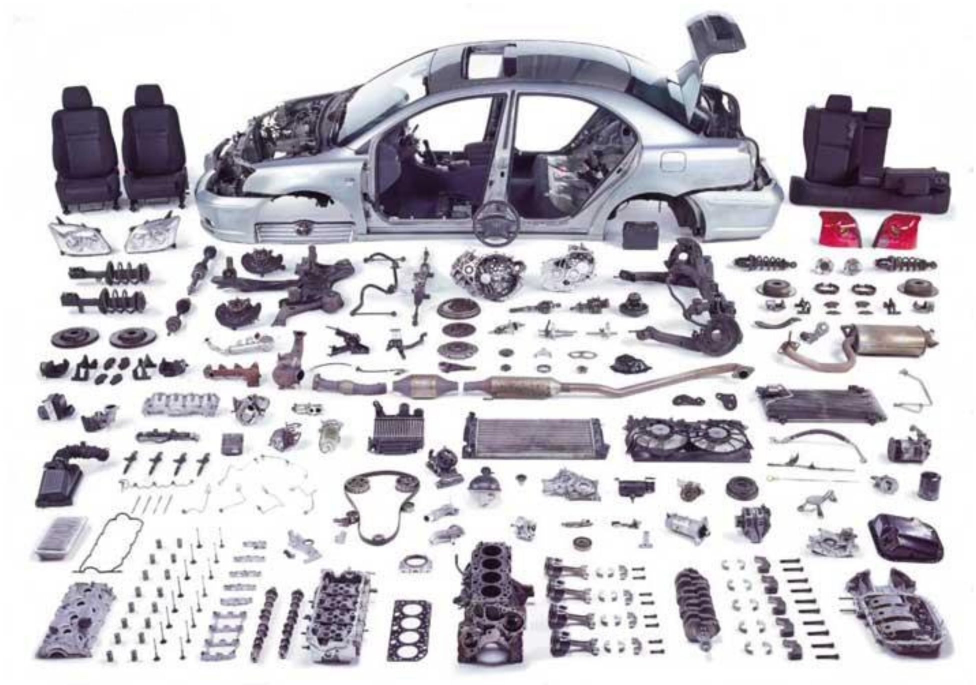


Fig. 1 Overview of components in the car

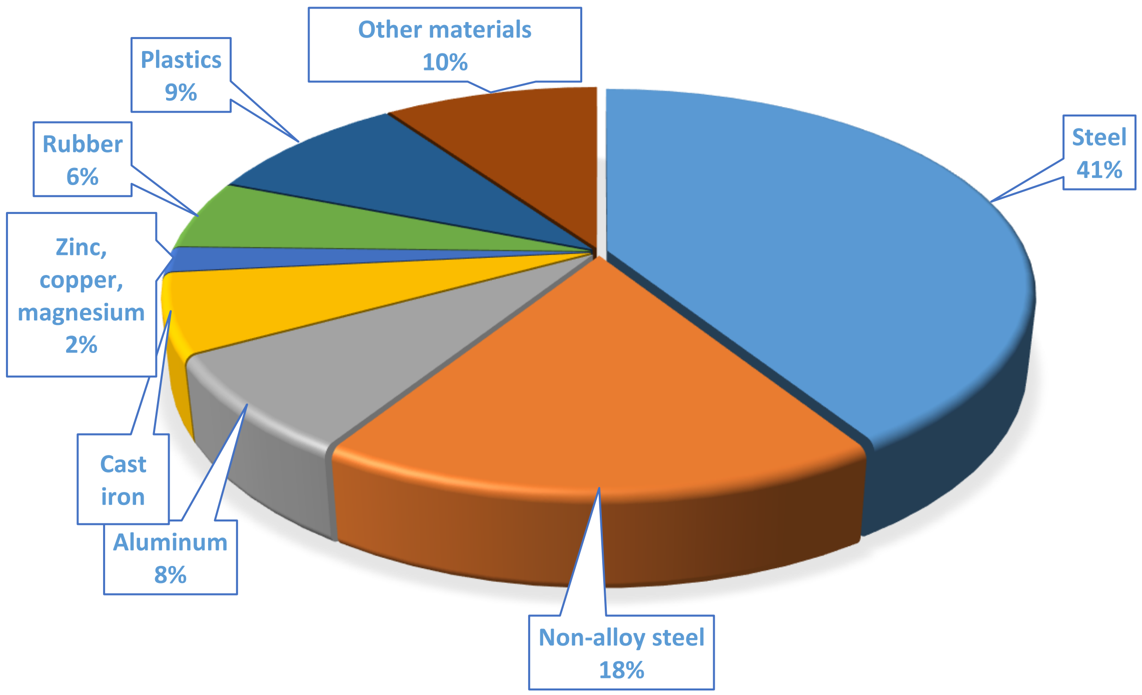


Fig. 2 Material composition of the car in %

Car production process

In Fig. 3 you can see the course of the main processes in the production of the car in the automotive company. The principle of automotive company operation is based largely on assembly processes. The blue line represents the operation of the vehicle body processes until its final assembly and the green line represents the completion of the vehicle's powertrains (engine, transmission, exhaust system, etc.), which are mounted in the vehicle body only in the final assembly. [5, 9]

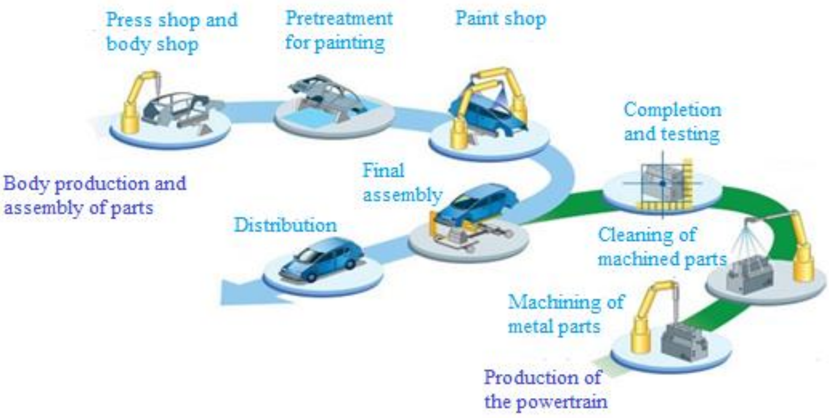


Fig. 3 The course of the main processes in the production of a car

1. Press shop

In the press shop (Fig. 4) the whole process of car production begins, where the individual body parts are produced by a technological process, pressing. The process begins in such a way that pieces of sheet metal of the desired size are cut from a roll of sheet metal, which is unwound, subsequently cleaned, levelled, which then travel to the pressing machine. In the pressing machine, a pressing process is thus created and finished mouldings are formed, which travel to the next process of the car producer, i.e. body shop.

Fig. 4 Example of a press shop

2. Body shop

The second production process in the automotive factory, which works with a help of number of robots (Fig. 5), which perform a number of functions (including feeding, welding, etc.), thus forming the body skeletons from the individual profiles and mouldings created in the previous moulding process. The skeleton thus forms the basis of the car, it is its supporting part, on which all other components are further assembled. The vehicle begins to have the contours of its future form. The result in the body shop is the skeleton of the vehicle and its body, which then travels to the paint shop. In Fig. 6 it is possible to see the individual parts of the vehicle body.

Fig. 5 Example of body shop with robots

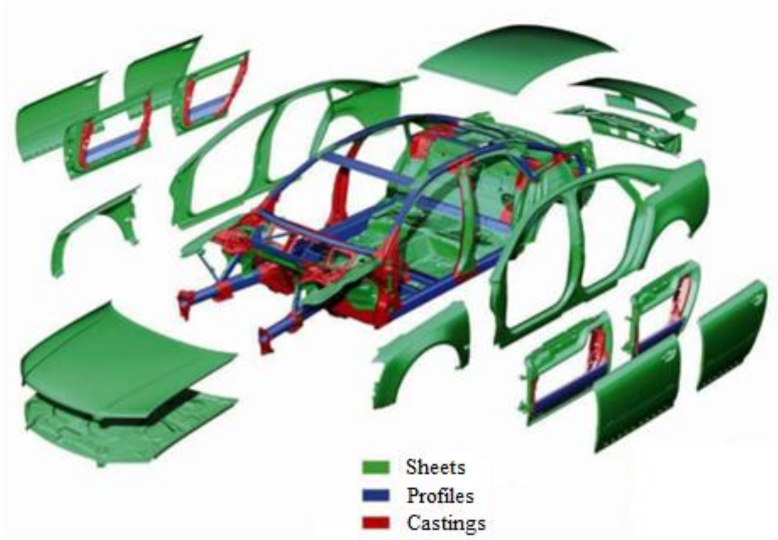


Fig. 6 Parts of car body

3. Pre-treatment body for painting

It is a very important process, because it has a great impact on the quality of the resulting vehicle body paint. It is divided into three phases:

- Degreasing – It dissolves and removes all dirt from the body, such as oil, etc.
- Rinsing – It removes dirt residues by rinsing the body.
- Phosphating – It protects the surface from water.

Subsequently, the cleaned and surface-treated body travels to the paint shop.

4. Paint shop

After accurate cleaning of the body, the paint application process is as follows:

- Cataphoresis – is an electrophoretic method of applying tricationic phosphate by immersion, where the body is a cathode that attracts cations of paint. Subsequently, the layer hardens at a temperature of 180 ° C for about 30 minutes. It is the best method of body surface treatment. This process is illustrated in Fig. 7

Fig. 7 Example of cataphoresis process

- Basic color (filler) – another layer, which is applied to the vehicle body and is applied in three stages:
    - spraying the surface,
    - manual spraying of hard-to-reach places,
    - completion of spraying.

  After spraying, the bodies are dried at 180 ° C and then cooled to 40 ° C.
- First and second layer of paint – in this phase, the first and then the second layer of paint is sprayed onto the base paint.
- Final layer – application of wax and preservative spray.

5. Final assembly

It takes place on assembly lines, where individual parts and components are assembled into an already painted and surface-treated body. Automation and robotization are widely used. The process consists of identification of the body to complete the vehicle according to the exact requirements of the customer. Subsequently, the assembly of individual parts, such as dashboards, seats, powertrains and others, takes place, which results in a complete car. The moment of body connection to the chassis is significant. Fig. 8 shows the final assembly of the car.

Fig. 8 Example of final assembly

6. Inspection and testing

The last hall that the car passes through in the production process is the inspection center, which consists of inspection and testing of the vehicle and subsequent possible correction of the identified deficiencies. For example, electronics, car control unit, dynamic properties on the test circuit, water test and others are checked.

7. Distribution

After inspection and testing, the car is distributed to stores and showrooms, where it is already fully functional and ready for its future owner.

Conclusion

The coronavirus-causing COVID-19 pandemic has almost sopped car production worldwide. According to the Slovak Investment and Trade Development Agency (SARIO), there are 350 medium-sized and large companies in Slovakia, which produce components necessary for the production of vehicles. Ultimately, the crisis in the automotive industry is affecting 50 % of industrial production in Slovakia, including a number of smaller companies.
These companies are connected not only to Slovak car manufacturers. Components made in Slovakia usually travel to customer plants of various producers in Europe, Asia and North America. And it is the automotive industry that has experienced perhaps the biggest crisis in history due to the coronavirus pandemic.
It is clear that the new start in the automotive industry is and will be gradual, and it is therefore important for car manufacturers to realize that now more than ever, the customer is the decisive element. Many car manufacturers therefore decided to respond to the current situation in the world and launched the so-called "contactless" test drives and "door to door" car delivery, began working on special "disinfected" vehicles with drone delivery of keys to buyers, or even testing a system to perfume vehicle models with the aroma of traditional Chinese medicine.

This article was created by implementation of the grant project VEGA 1/0438 / 20 Interaction of digital technologies to support software and hardware communication of an advanced production system platform.

References

[10] BOROŠKA, J., MARASOVÁ, D.: Dopravné systémy, Strojnícka fakulta TU v Košiciach, 2000, 104 s. ISBN 80-70999-612-9.

[11] KOVÁČ, J., RUDY, V., KOVÁČ, J.: Automatizácia výroby, Strojnícka fakulta TU v Košiciach, 2016, 304s. ISBN 978-80-553-2311-4.

[12] KOVÁČ, M. – BABJAK, Š.: Integration of Product Innovation Techniques in Automotive Component Design. In: Acta Mechanica Slovaca, roč. 14, č. 1/2010. Košice, SjF TU v Košiciach, 2010, s. 42 – 53. ISSN 1335-2393

[13] KOVÁČ, M. a kol.: Product design v automobilovej výrobe, Košice, TUKE, SjF, Edícia EQUAL, 2006, 110 s., ISBN 80-8073-687-1

[14] PHAAL, R.: Foresight Vehicle Technology Roadmap: Technology and Research Directions for Future Road Vehicles. Londýn: Department of Trade and Industry, 2002. URN 02/933

[15] RAJENDER, S.: Introduction To Basic Manufacturing Process & Workshop Technology, New Age International, 2006, 506 s. ISBN 81-2241-846-5

[16] SENDERSKÁ, K., RUDY, V., MAREŠ, A.: Montáž v automobilovej výrobe, Strojnícka fakulta TU v Košiciach, 2010, ISBN 978-80-553-0561-5.

[17] SPENCE, A. D.: Mechanical engineering – Product design. USA: McGraw-Hill Primis, 2008. 321s. ISBN-13:978-0-39-044050-1.

[18] TOMEK, G., VÁVROVÁ, V.: Řízení výroby, Praha 7: Grada publishing. 2000. 408 s. ISBN 80-7169-955-1.

Contact adress
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
E-mail: peter.malega@tuke.sk

Review process
Single-blind peer review process.

MAPPING OF CIRCULAR ECONOMY INDICATORS ON MICRO LEVEL BASED ON PRODUCT LIFE CYCLE AND RESOLVE FRAMEWORK

Juraj ŠEBO

Abstract: The objective of this paper is to map CE indicators on micro level based on product life cycle and ReSOLVE framework. 62 micro level CE indicators were identified based on actual studies. The highest numbers of indicators are in Loop and Optimize action on the side of ReSOLVE framework and in EOL phase, whole life cycle and Use phase on the side of product life-cycle phases. The most indicators cover EOL life-cycle phase (21) and Loops ReSOLVE action (19). Found uneven distribution of micro level CE indicators according to product life-cycle phases and six ReSOLVE business actions led us to the question, if current package of the indicators correctly describes whole picture of companies' progress towards CE.
Keywords: circular economy, indicator, life cycle, ReSOLVE

Introduction

The circular economy concept is to an increasing extent penetrating political, scientific and also business sphere of the society. The CE concept in eco-industrial perspective could be understood as “realization of closed loop material flow in the whole economic system” (Geng, 2008). Simultaneous consideration of economic and environmental side is present in Ellen Macarthur Foundation (2013) definition of CE as “an industrial economy that is restorative or regenerative by intention and design”. Korhonen (2018) argue that there is quite little that is truly new in the CE concept in terms of sustainability science research, except for it highlights the importance of high value and high-quality material cycles in a new manner and it shows the possibilities of the sharing economy. In addition, Kristensen (2020) stated, that the assumed sustainability benefits of CE are not yet understood in practice, although CE is highlighted as having the potential to support sustainable development.

CE studies follow three main lines of action: the first aims to change the social and economic dynamics at macro and administrative level; the second to support firms in circular processes implementation at micro level to spread new forms of consumption and product design; the third, developed at meso level, discusses industrial symbiosis experiences (Merli, 2018). Lieder (2016) suggests that simultaneous focus on the three perspectives ensures concurrent and equivalent visibility of limitations of natural resources, environmental concerns including waste and individual business needs. He also concludes that for succeeding in CE implementation a concurrent top-down and bottom-up strategy is required to maintain the interests of all stakeholders, i.e. policy makers, governmental bodies and manufacturing industries. Despite his arguments there is number of CE studies (e.g. (Kristensen, 2020; Kravchenko, 2019)) that focus on one level, in this case on micro level. In line with these studies, our study focuses on micro level CE indicators. The goal of the study is to identify and map relevant micro level CE indicators according to product life cycle and ReSOLVE framework.

CE indicators on micro level

Elia (2017) stated that currently there is no standardized way to measure micro level circularity. Also Cayzer (2017) stated that “product circularity depends on the lens through which it is

viewed”, in other words could mean different understandings of what matters when measuring circularity by different CE indicators.
Kristensen (2020) found in 30 reviewed micro level CE indicators three types: single quantitative indicators, analytical guidelines or tools, and composite indicator set. Their even distribution also demonstrates a diverse approach to measuring CE. The diversity is also evident in number of principles entailed in the indicator ranging from one (e.g. recycling) to a broad CE perspective of multiple CE principles. In addition, the study shows that on micro level the indicators for recycling are more developed than indicators for reuse and repair, while no indicator clearly considered the inner circle of repair and maintenance in measurable ways. It also shows the limited inclusion of all three dimensions of sustainability (economic, environmental and social) in micro level CE indicators, while economy has more weight, and environmental and especially social aspects are downgraded. As she further pointed out, the indicators for CE should consider a prioritization of CE principles to be able to fully capture the potential benefits of CE, and not equate reuse with recycling, which is often the case for CE indicators at micro level. In addition she pointed out the issue of sub-optimization, which could be relevant if we focus on e.g. recycled content, which could be easily increased by e.g. increase in overall weight of the product, but could negatively influence other CE principles, e.g. reduction of material use. As she concludes, this above presented diversity of type, entailed principles and sustainability dimensions makes the landscape of micro level indicators difficult for organizations to navigate within, what is further emphasized by the risk of sub-optimizations and trade-offs when employing indicators, and more attention must be paid to the interconnection between the three sustainability dimensions and prioritization of CE principles in micro level CE (Kristensen, 2020).

Mapping of CE indicators on micro level based on product life cycle and ReSOLVE framework

In this part of the paper the mapping of relevant micro level (i.e company level) CE indicators is presented. 62 micro level CE indicators were identified based on actual studies (e.g. (Kravchenko,2019; Kristensen, 2020; Rincón-Moreno, 2021; Rossi, 2020; Esposito, 2015; Govindan, 2020)). The studies were searched in Google Scholar and ScienceDirect database by key words “circular economy” +“indicator”.
The study systemizes 62 identified indicators according to two relevant characteristics, the life cycle phase and ReSOLVE actions. The considered life cycle phases are raw material extraction, production, use and end of life phase (see e.g. (EUROPEAN ENVIRONMENT AGENCY, 2018)), to which were added product design phase and distribution/transportation phase. The considered ReSOLVE actions: Regenerate, Share, Optimize, Loops, Virtualize, Exchange are six business actions to guide organizations through implementing the principles of the CE (Ellen MacArthur Foundation 2015). The following table (Tab. 1) shows number of indicators in each life cycle phase, and for each phase it also shows their distribution in relation to ReSOLVE actions. We can see the highest numbers of indicators in Loop and Optimize on the side of ReSOLVE actions and in EOL phase, whole life cycle and Use phase on the side of product life cycle phases. The most indicators cover EOL life cycle phase (21) and Loops ReSOLVE action (19). Figure 1 shows how many of researched micro level CE indicators are relevant to each product life cycle phase and whole life cycle. Figure 2 shows how many of researched micro level CE indicators are relevant to different ReSOLVE action and to whole ReSOLVE framework.

Tab. 2 Mapping of CE indicators according to six life cycle phases and six ReSOLVE actions

	Regenerate	Share	Optimize	Loops	Virtualize	Exchange	Whole ReSOLVE framework	Not fitting to any group	Lack of information for assignment	Total
Product design	2	1			1					4
Raw material extraction					1					1
Production / manufacturing	1		1	1						3
Distribution / transportation			3							3
Use / maitanance		5		2	1					8
End-of-life management			2	15		3		1		21
Whole life-cycle	1		7	1	1	2	3	1	1	17
Not fitting any stage										0
Lack of information for assignment									5	5
Total	4	6	13	19	4	5	3	2	6	62

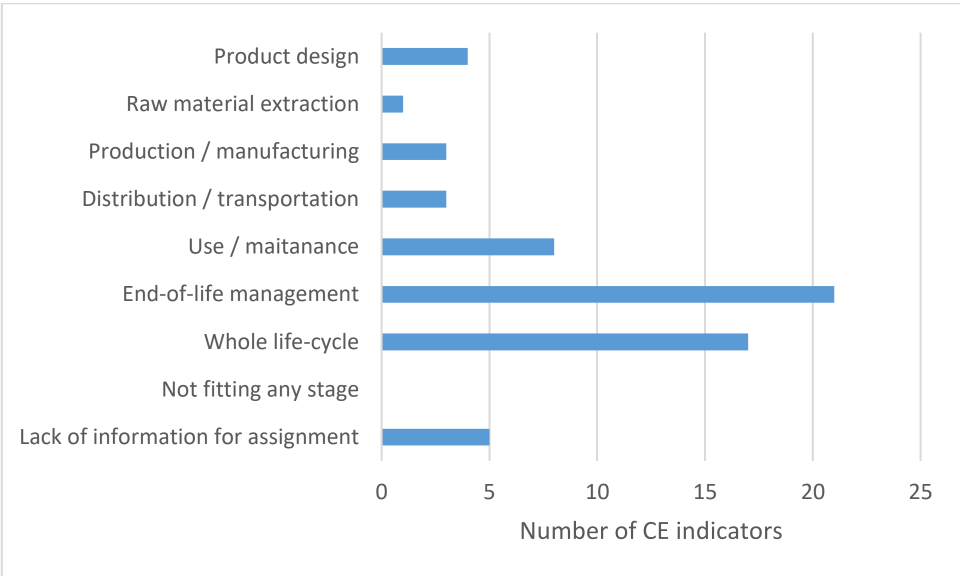


Fig. 1 Comparison of the number of micro level CE indicators relevant to different life cycle phases

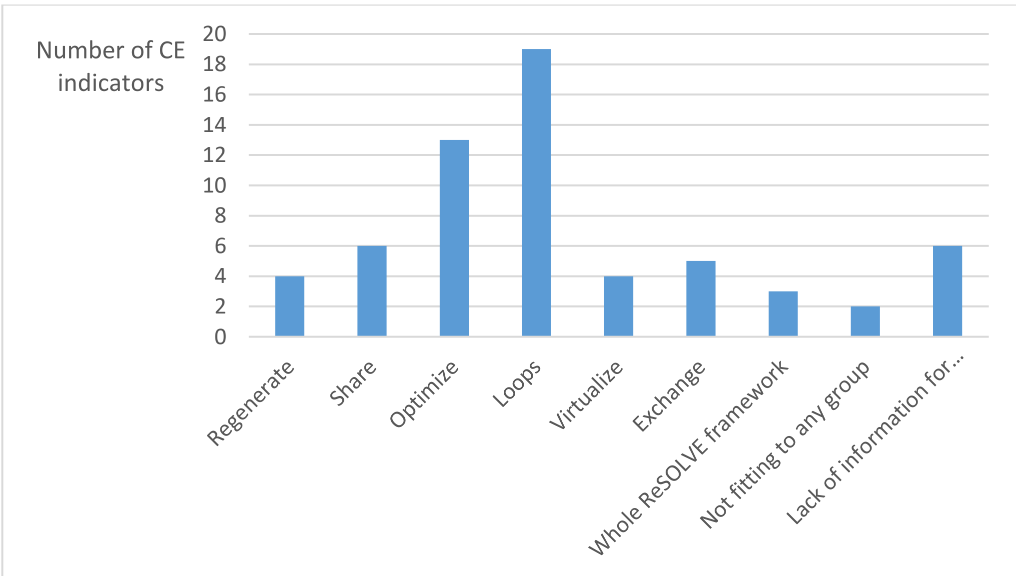


Fig. 2 Comparison of the number of micro level CE indicators relevant to different ReSOLVE actions

Conclusion

The present study showed uneven distribution of micro level CE indicators according to product life cycle phases and according to six ReSOLVE business actions. It led us to the question, if current package of micro level CE indicators correctly describes whole picture of companies' progress towards CE.

Acknowledgement

This contribution was supported by the research grant VEGA 1/0438/20 Interaction of digital technologies to support software and hardware communication of the advanced production system platform.

References

[1] CAYZER, Steve, GRIFFITHS, Percy and BEGHETTO, Valentina, 2017. Design of indicators for measuring product performance in the circular economy. International Journal of Sustainable Engineering. 3 September 2017. Vol. 10, no. 4–5, p. 289–298.

[2] ELIA, Valerio, GNONI, Maria Grazia and TORNESE, Fabiana, 2017. Measuring circular economy strategies through index methods: A critical analysis. Journal of Cleaner Production. 2017. Vol. 142, p. 2741–2751.

[3] ELLEN MACARTHUR FOUNDATION, 2013. Towards the Circular Economy.

[4] ELLEN MACARTHUR FOUNDATION, 2015. Why the circular economy matters. Delivering the Circular Economy: A Toolkit for Policymakers. 2015. p. 19–32.

[5] ESPOSITO, Mark, TSE, Terence and SOUFANI, Khaled, 2015. Is the Circular Economy a New Fast-Expanding Market? Thunderbird International Business Review. 2015. Vol. 59, no. 1, p. 9–14.

[6] EUROPEAN ENVIRONMENT AGENCY, EEA Report No 13/2018, Publications Office of the European Union, 2018

[7] GENG, Yong and DOBERSTEIN, Brent, 2008. Greening government procurement in developing countries: Building capacity in China. Journal of Environmental Management. 2008. Vol. 88, no. 4, p. 932–938.

[8] GOVINDAN, Kannan, MINA, Hassan, ESMAEILI, Ali and GHOLAMI-ZANJANI, Seyed Mohammad, 2020. An Integrated Hybrid Approach for Circular supplier selection and Closed loop Supply Chain Network Design under Uncertainty. Journal of Cleaner Production. 2020. Vol. 242, p.1-16

[9] KORHONEN, Jouni, HONKASALO, Antero and SEPPÄLÄ, Jyri, 2018. Circular Economy: The Concept and its Limitations. Ecological Economics. 2018. Vol. 143, p. 37–46.

[10] KRAVCHENKO, Mariia, PIGOSSO, Daniela CA and MCALOONE, Tim C., 2019. Towards the ex-ante sustainability screening of circular economy initiatives in manufacturing companies: Consolidation of leading sustainability-related performance indicators. Journal of Cleaner Production. 2019. Vol. 241, p. 1-19.

[11] KRISTENSEN, Heidi Simone and MOSGAARD, Mette Alberg, 2020. A review of micro level indicators for a circular economy – moving away from the three dimensions of sustainability? Journal of Cleaner Production. 2020. Vol. 243, p. 1-20.

[12] LIEDER, Michael and RASHID, Amir, 2016. Towards circular economy implementation: A comprehensive review in context of manufacturing industry. Journal of Cleaner Production. 2016. Vol. 115, p. 36–51.

[13] MERLI, Roberto, PREZIOSI, Michele and ACAMPORA, Alessia, 2018. How do scholars approach the circular economy? A systematic literature review. Journal of Cleaner Production. 2018. Vol. 178, p. 703–722.

[14] RINCÓN-MORENO, J., ORMAZÁBAL, M., ÁLVAREZ, M. J. and JACA, C., 2021. Advancing circular economy performance indicators and their application in Spanish companies. Journal of Cleaner Production. 2021. Vol. 279. p. 1-10
[15] ROSSI, Efigênia, BERTASSINI, Ana Carolina, FERREIRA, Camila dos Santos, NEVES DO AMARAL, Weber Antonio and OMETTO, Aldo Roberto, 2020. Circular economy indicators for organizations considering sustainability and business models: Plastic, textile and electro-electronic cases. Journal of Cleaner Production. 2020. Vol. 247. p. 1-16

Contact address
doc. Ing. Juraj Šebo, PhD.
Technical University of Košice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenského 9, 042 00 Košice, Slovakia
e-mail: juraj.sebo@tuke.sk

Review process
Single-blind peer review process.

ERGONOMICS IN THE HEALTHCARE

Ivona FILIPOVÁ – Ľuboslav DULINA – Martin GAŠO – Eleonóra BIGOŠOVÁ

Abstract: Today's times offer several technical options to make work easier. Applying ergonomics at work means that we try to find the simplest possible way for the worker to work while maintaining high quality and productivity. We meet this quite often in production, but in the area of providing services, it is rare. The field of healthcare is hectic today. This article, therefore, addresses the need to assess ergonomics in the healthcare area and how to solve problems of staff.
Keywords: Ergonomics, Nurse, Working position, Evaluation of work

Introduction

The role of ergonomics is to adapt work to human needs. While in the industry, we can already observe the effort to look at work ergonomically, in the healthcare area, this is not very widespread. Nevertheless, there is a need to evaluate ergonomics in this segment, as well, handle medicines, laboratories samples [1,2]. The largest group of staff caring for patients are nurses. They are spending most of the working day caring for patients. Handling them is very specific. The patient is not a classic load. It does not have special grips, it moves during handling and also has a weight which, in the case of adults, often exceeds the legislation work limits several times over. These are also the reasons why nurses exposed to significant physical and mental pressure in their work. The psychological side is relatively difficult to assess. These are subjective feelings that can only be collected as information from the observed person. We are all different; we react differently to situations. In contrast, physical activity can be assessed both subjectively and objectively by the observer.

Profession of nurse

The reason why nurses were chosen for the evaluation is that with a share of 40 %, they form the majority of employees in health care. However, their number is declining but declining every year. Majority of nurses are women. Men make up only about 2 % of all nurses. This job is often physically hard, and therefore more suitable for men.
Another problem is the increasing proportion of nurses aged 40 and over. In 2009 the proportion of nurses aged 40 and older was 56.4 %. There was 3.8 % over 60, which means women in almost retirement and retirement age. Until 2018, this figure had risen to 76.1 %. There is now 10.2 % of nurses over 60 years old [2].

Problems in the work of nurse

The problem with the growing age of the nurses is that with increasing age, the limit for the maximum possible weight of the load (patient) decreases. Besides, the table provides for a maximum age of 60 years, so the weight limit for older working women should be even lower, but its value should not be specified. Weight limits for loads with the indication of the maximum age and limits for women are in Tab. 1. Exceeding the weight limits leads to overweight and exhaustion, which is unacceptable for ergonomics.

Tab. 3 Load weight limits [3]

Age	Conditions	Maximum load weight (kg)		Maximum load weight per shift (kg)	
		Men	Women	Men	Women
18 – 29	favorable	50	15	10000	6500
	unfavorable	40	10	8000	5500
30 – 39	favorable	45	15	7500	6500
	unfavorable	40	10	7200	5500
40 – 49	favorable	40	15	6500	6500
	unfavorable	35	10	6000	5500
50 – 60	favorable	35	15	5500	5000
	unfavorable	30	5	5000	4000

Many overtime hours and their low payment are showing to be a problem. In a research made by the Slovak Chamber of Nurses and Midwives states that up to 53 % of respondents work more than 23 hours overtime, while only 42.3 % of them have paid for it. That means overworking, but also frustration with inadequate financial appreciation [4].

Risks in the work of nurse

There are various risks involved in this profession that can cause injuries. The breakdown of these threats is below:

Risks associated with work responsibilities

• Application of force: the degree of physical effort required to perform an activity (such as lifting heavy loads, moving and towing) or to maintain equipment and tools. Safe patient handling techniques are one of the essential preconditions for the prevention of spinal cord injury. Therefore, they should be given increased attention. The current trend is aimed at minimizing the tasks associated with lifting and carrying the patient and the application of appropriate technical means. The emphasis is on patient cooperation.

• Repetition: continuous or frequent execution of the same movement or series of movements during working hours.

• Improper positions: adopted positions that strain the body, such as leaning over the bed, kneeling or rotating the torso during lifting.

Risks associated with patient

Patients cannot be lifted as classic loads. Safe rules cannot be used when handling a patient:

• Patients cannot be kept close to the body.
• Patients do not have handles.
• It is never possible to predict what will happen during patient handling.
• Patients are obese.

Risks associated with surroundings

• Risk of slipping, tripping and falling.
• Uneven work surfaces.
• Space limitations (small spaces, lots of equipment).

Other risks

• Help is not available.
• Unsuitable equipment.
• Unsuitable footwear and clothing.
• Lack of knowledge or insufficient training [5]

The dangers arising from patient manipulation are mainly related to the spine. It is most loaded with simultaneous pressure and rotation. The riskiest part of the spine is the bottom part (L5 / S1). Fig. 1 shows the spine and the movements that occur on it during the manipulation of the patient. Because of this, there is no gentle way to manipulate the patient. There may come the danger of Musculoskeletal disorders. The physical effort required to lift and move the patients repeatedly is more significant than the musculoskeletal system can tolerate [6].

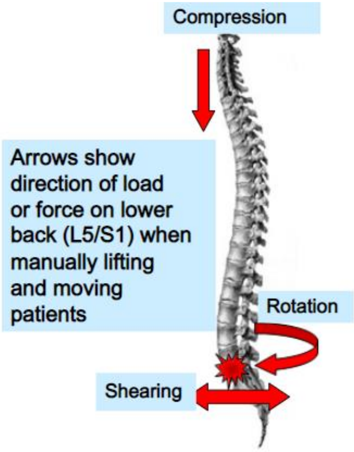


Fig. 3 Movement of the spine under load [6]

There are various principles of handling to reduce these risks. Here are some of them:

- Principles of load handling.
- Principles of kinesthetics.
- Principles of solid parts and gaps.

All these principles are intended to facilitate and simplify the work and also to involve the patient himself in the process of transferring himself as much as possible. Education in the field of ergonomics, which approximates the above-mentioned principles, is already included in the secondary school study.

Scientific problem

Specific activities in the work of nurses and requirements for workplace types of equipment also require specific evaluation. Despite the existence of general evaluation methods, these are not suitable for the overall evaluation of all, especially specific activities in terms of the application of ergonomics. Therefore, within the research in the Department of Industrial Engineering at UNIZA, a procedure was created aimed at evaluating the work of nurses, which takes into account all the specifics. We are currently working on its verification in real conditions.

Evaluation of ergonomics in the workplace

The ward of the surgical intensive care unit (ICU) in the Hospital with a polyclinic in Považská Bystrica was selected for the evaluation by the proposed procedure. Ergonomics was evaluated by a new evaluation procedure created in the Department of Industrial Engineering at the University of Žilina. The evaluation was made by marking information in worksheets in the xlsx format. In this ward work a total of 10 nurses, and their shifts takes 12 hours. There can be a maximum of six patients in the ward, and this capacity is usually full. The nurses were evaluated on the morning shift; there are two in the ward during the service. There were six patients in the ward during the evaluation.

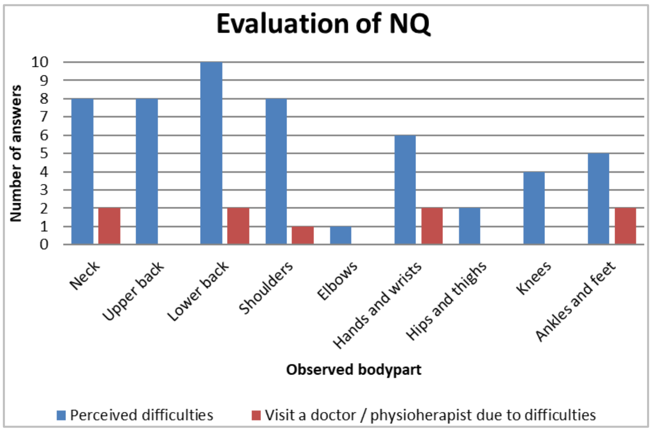
Fig. 4 Selected ward [7]

Workplace analysis

The subjective analysis was performed using a modified Nordic Questionnaire (NQ). Questions were adapted specifically for the work of sisters. There are four different parts:

- 1. Part – General Information.
- 2. Part – Subjective evaluation of difficulties with the musculoskeletal system.
- 3. Part – Subjective evaluation of the response to specific situations.
- 4. Part – Knowledge and use of specific terms [8].

After the evaluation of NQ, the age structure of nurses was determined, shown in Graph 3. The graph shows that in the age group 18 - 29 years there is only one nurse. There is five nurses in the age group of 30 - 39 years and two nurses aged 40 - 49 and 50 - 60 years in each group. Graph 4 evaluates the difficulties experienced in each part of the body and visits the doctor because of them. Most of the nurses experience or have experienced difficulties, very few of them have even visited a doctor because of this.



Graph 1 Evaluation of difficulties from NQ

In Tab. 2, there is an evaluation of the feeling loaded from individual work activities. They were evaluated according to the Borg scale, where the answers were marked from 0 to 10, according to the subjective feelings. The most difficulties for nurses are lifting and carrying the load/patient. These are the activities in which they have to exert the most significant amount of force. Based on the average values, we can say that the nurses feel a medium loaded in their work, as most of the values are in this interval. A small load was indicated when working with the hands overhead. The situation occurs, especially when administering infusions, blood, or setting up monitors that measure the patient's vital signs and are located above his bed.

The lowest feeling of the load is given in situations involving the temperature in the workplace, which is the ward is air-conditioned and thanks to the possibility of setting a pleasant temperature, almost no load is created.

Tab. 4 Evaluation of load

Sitution	No load			Low load			Medium load			High load		Average values
	0	1	2	3	4	5	6	7	8	9	10	
Lifting, carrying the patient								2		6	2	9
Rushing / time pressure							4		1	1	4	8
Long-time work in the same positions						3		2		1	4	8
Forward bend, torso rotation						1		2	5	2		8
Overtime work, long work shifts						2		3	3	1	1	7
Work on the edge of physical strength						2	1	2	3	2		7
Poor quality of handling aids			1				1	4	2	1	1	7
Insufficient rest breaks						4	2		1		3	7
Uncomfortable working position						3	2	4		1		6
Bad training on how to work properly			1		1		3	3	1	1		6
Working overhead			1		3	4	2					5
Cold, heat, humidity in the workplace		3	4	2	1							2

The last part of the NQ is supplementary questions. These are aimed at finding out the knowledge of nurses of terms that should be known and helpful at work, and if they even use them. These are principles that help make it easier to work with the load. Their use can eliminate the possibility of injury, for example, in the sacral area, which is one of the most stressed areas on the body. Four questions were asked, which are discussed in detail below, along with an evaluation of the answers. The questions, together with the possible answers and the number of answers, are listed below, in Fig. 3.

1. Do you know the concept of ergonomics?	
1. Yes, I know what ergonomics is	9
2. I have heard, but I can't explain	1
3. No, I have never heard before	0

3. Do you know the concept of kinesthetic?	
1. Yes, I know what kinesthetic is	7
2. I have heard, but I can't explain	2
3. No, I have never heard before	1

2. Do you know the principles of proper handling of heavy loads / patients?	
1. Yes, I know this principle	7
2. I have heard, but I can't explain	3
3. No, I have never heard before	0

4. Do you know the principle of solid parts and gaps?	
1. Yes, I know this principle	3
2. I have heard, but I can't explain	2
3. No, I have never heard before	5

Fig. 5 NQ supplementary questions

Above answers says that these are principles that nurses should know, but not all of them use them or know them at all. These are terms that should be known to them from high schools. It is, therefore, necessary to include this topic more in teaching at secondary schools and universities, or in training that takes place even during employment. That is about the health of both nurses and patients. By proper handling, we can reduce the risk of injury or the occurrence of an occupational disease.

The objective analysis assessed the factor of work duration and personnel and material security. The overall assessment of these factors pointed to a possible risk of damage to health. The evaluation sheet with the values XX at the given workplace is shown in Fig. 4

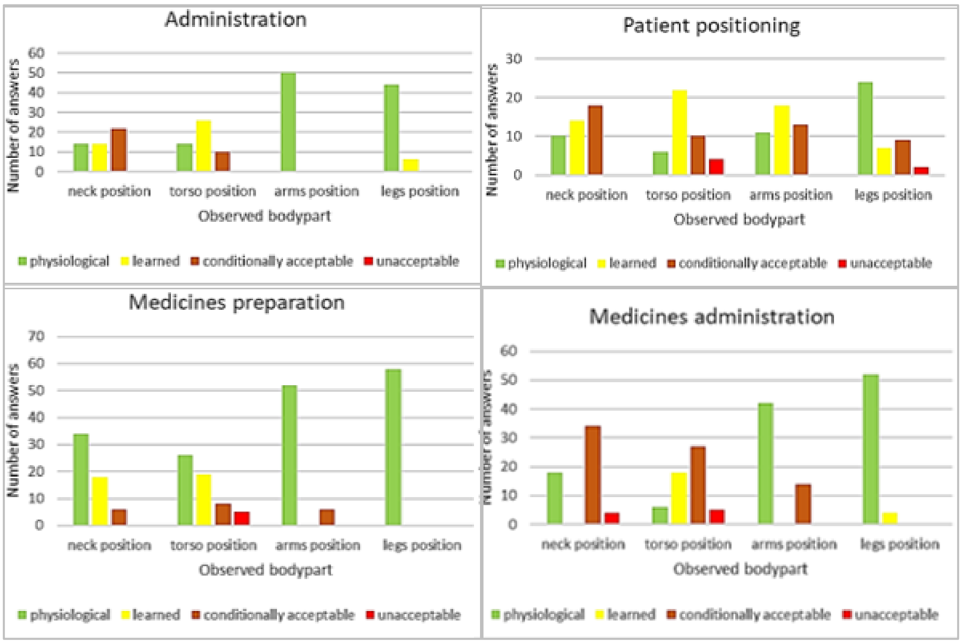
PHYSICAL LOAD IN THE WORK OF NURSES			
Rough evaluation			
Factor: duration of work	Duration of workshift [min]	Duration of breaks [min]	Total duration of work [min]
	720	30	690
	Total score		
	1,50		
Factor: personnel and material equipment	Personnel equipment		
	Number of patients per ward	Number of nurses per ward	Number of patients per nurse
	6	2	3
	Total score		
	1,00		
	Material equipment		
	Number of adjustable beds	Number of beds trapeze	Number of wheelchairs
	6	6	0
	Partial score		
	1	1	2
	Total score		
	2,00		
Risk of health damage due to physical activity			
Evaluation	Description and recommendation		
3,0	The risk of health damage due to physical activity is moderate. There is a possibility of health damage due to physical activity in less physically fit individuals. Corrective measures should be considered.		

Fig. 6 Evaluation sheet

In the detailed evaluation, the observed activities were divided into four groups, according to the type of work performed. The categories of work are divided as follows:

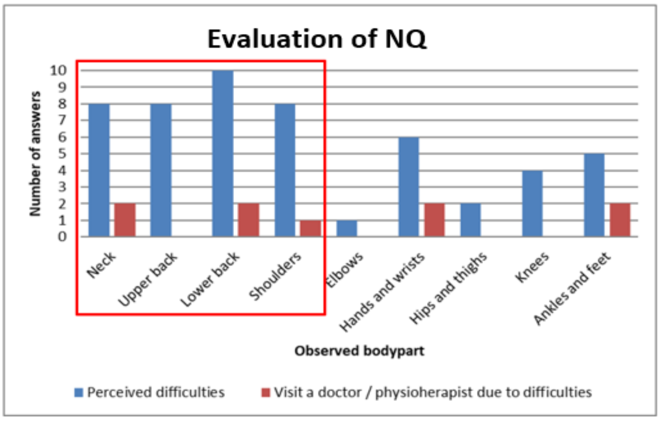
• Administration – a depreciation of medicines to patients, registration of new and disposal of patients,
• Patient positioning – helping the patient to change position to lie down, sit down, get up, help with changing clothes,
• Medicines preparation – tablets, injections, blood for transfusion, infusions,
• Medicines administration – mentioned in the previous category.

It can be seen from Graph 2 that the number of non-physiological positions (learned, conditionally acceptable, unacceptable) is highest in patient positioning and medicines administration. Patient handling makes up the majority of nurses worktime. It is necessary to take corrective measures that increase the number of physiological positions in order to prevent the development of damage to health.



Graph 2 The evaluation of all work categories

When comparing the perceived difficulties of nurses and the highest incidence of non-physiological positions of the body at work, it was found that most of them are located in body parts that the nurses mentioned as the body parts where they feel the most difficulties. The intersection is shown in red in Graph 3.



Graph 3 Intersection of physiological and non-physiological body positions

Recommendations for corrective measures

The results show that the ergonomics in the ward is not right. It, therefore, needs to be solved. It should be started by teaching about existing principles that will increase nurses' knowledge of safe work and reduce the risk of injury. However, no manual handling is entirely safe. Since the most significant risk came from manipulating the patient, nurses need to be relieved the most in this area. In this, handling aids such as lifting devices for handling the patient, which would do this most massive work instead of nurses, will help. The price of this device is around 1000 €.

Conclusion

Based on the performed analysis, it was found that it is necessary to solve ergonomics in healthcare, due to its insufficient provision. Improving teaching in schools and trainings would increase nurses' awareness of safer and easier work. Learning could also prevent the emergence of new learned positions that are not physiological. Nevertheless, it is necessary to provide a lifting device that did the most heavy work - lifting and transporting patients instead of nurses. The role of nurses in the patient's treatment process is irreplaceable and therefore care must be taken to ensure their health and well-being in the workplace.

Acknowledgments : "This work was supported by the KEGA Agency under the contract no. KEGA 022ŽU-4/2018”.

References

[1] PEDAN, M., GREGOR, M., PLINTA, D.: Implementation of Auto-mated Guided Vehicle System in Healthcare Facility. In: Pro-cedia Engineering, vol. 192/2017, University of Zilina, Horny Smokovec, 2017.05.31, p-ISSN: 1877-7058, pp. 665-670.
[2] PÁSTOR, M., TREBUŇA, F., LENGVARSKÝ, P., BOCKO, J.: Possibility of Using of Tensometry in Deformation Analysis in Areas With Sudden Change of Geometry. In: American Journal of Mechanical Engineering, Vol.4, No.7, 2016, pp363-367
[3] Národné centrum zdravotníckych informácií 2018. Zdravotnícka ročenka Slovenskej republiky 2018. Dostupné na internete: http://www.nczisk.sk/Documents/rocenky/2018/Zdravotnicka_rocenka_Slovenskej_republiky_2018.pdf (cit. 2020-02-10)
[4] Nariadenie vlády Slovenskej republiky č. 281/2006 z 19. apríla 2006 o minimálnych bezpečnostných požiadavkách pri ručnej manipulácii s bremenami.
[5] Slovenská komora sestier a pôrodných asistentiek: TLAČOVÁ SPRÁVA: Pracovné podmienky sa sestrám a pôrodným asistentkám napriek ich nedostatku, v roku 2019 výrazne nezlepšili. 2020. Dostupné na internete: https://www.sksapa.sk/obsah/tlacove-spravy-1/prehlad-tlacovych-sprav/tlacova-sprava-pracovne-podmienky-sa-sestram-a-porodnym-asistentkam-napriek-ich-nedostatku-v-roku-2019-vyrazne-nezlepsili.html (cit. 2020-09-10)
[6] IŠTOŇOVÁ M., PALÁT M., Čechová – Špirková A. Ergonómia a prevencia v práci sestry 2009. Dostupné na internete:http://www.pulib.sk/web/kniznica/elpub/dokument/Mizenkova1/subor/24.pdf (cit. 2020-09-11)
[7] GADSBY R. 2004. Safe Patient Handling Program: Applied Ergonomics for Nurses and Health Care Workers. Dostupné na internete: https://slideplayer.com/slide/4180705/ (cit. 2020-11-09)
[8] KOPPOVÁ, I. 2020. Application of ergonomics in the work of nurses in selected department of medical facility: Diploma thesis. Žilina: University of Žilina. 63 p.
[9] ČECHOVÁ, I. 2019. Applying the principles of ergonomics to selected employees in health care: Dissertation Thesis. Žilina: University of Žilina. 144 p.

Contact address

Ing. Ivona Filipová
University of Žilina, Faculty of Mechanical Engineering, Department of Industrial Engineering, Univerzitná 8215/1, 010 26 Žilina, Slovakia
e-mail: ivona.filipova@fstroj.uniza.sk

Review process

Single-blind peer review process.

EXOSKELETONS AS ERGONOMIC CORRECTIVE MEASURE

Daniela ONOFREJOVÁ – Miroslav AGALAREV

Abstract: Manufacturers are experiencing an increased number of musculoskeletal disorders (MSDs). Their occurrence is not desirable not only for the health consequences on the human population, but also for economic consequences on employers. Preventive measures and identifying methods on how to work more preventatively with body parts ergonomics in early phases of product and production development are preferred. Studies to verify the suitability of exoskeletons as corrective measures are being performed and can be a benefit for the area.
Keywords: musculoskeletal disorders, exoskeletons, physical load, injuries, preventive ergonomics.

Introduction

Manufacturers worldwide, either in Slovakia, want to offer and maintain a safe work environment that meets or exceeds current standards and legislations globally. The motives include preventing injuries but also point to the physical and psychosocial aspects in all processes of the organization from product design to production processes [1]. Surveys in Slovakia, Europe [2 - 4] have observed an increased frequency of hand injuries among operators in the assembly plants, where manual operations are highly frequent. Compared to other engineering production processes, in assembly predominate particularly manual or mechanized hand work. In final assembly, hands are indispensable due to their ability of conducting precision work. [5]

Musculoskeletal disorders (MSDs) remain the most common work-related health problem in the European Union (EU) in all sectors and occupations. Besides the effects on workers themselves, they lead to high costs to enterprises and society [4]. Currently, studies are initiated in order to investigate possible clarification of the increase of injuries in upper body parts in the assembly operations [5], [6]. They want to identify methods on how to work more preventatively with body parts ergonomics in early phases of product and production development.

Preventing workers from suffering MSDs and promoting workers’ musculoskeletal health throughout their working life, from their first job onwards, are crucial to allowing them to work for longer. This therefore contributes to addressing the long-term effects of demographic ageing, in line with the Europe 2020 strategy’s objectives for smart, sustainable and inclusive growth. [4]

Injuries associated with lifting and shifting heavy workloads are a major problem for trade unions, human resources departments and government regulators. Reducing the workload, improving ergonomics and reducing the time spent moving heavy objects have been in a focus already, nevertheless workers are still injured. There are few options manufacturers have for change of situation: process redesign, automation, manipulators, etc., even exoskeletons could be a solution.

Exoskeletal devices are places on the user's body that act as amplifiers and multipliers to enhance or restore human performance. There are more and more applications for the exoskeleton, such as reduced fatigue and increased productivity when unloading or dropping material. Powered exoskeletal devices can easily allow a man to transport heavy objects

weighing up to 300 to 400 kg while running or climbing stairs, that is being developed for army purposes particularly.
On the other hand, for medical purposes, the exoskeleton can improve the quality of life of patients who have lost their legs, because its self-service system can easily help with walking or even running. After installation in the exoskeleton, the user can operate the device without the need for any external assistance. [6]
The field of exoskeletal systems is constantly evolving and re-emerging. In the past, exoskeletons were difficult to carry. Recent advances in robotics have helped create intelligent solutions that facilitate heavy loads from the backs of human workers.
Exoskeletons are used by various industries. In the medical field, patients were able to provide exoskeletons that allow paraplegics, people with disabilities as lost limb and others, to walk again. The agricultural industry involves considerable manual labor, so farmers can use exoskeletons to relieve the burden. Logistics companies see workers moving faster and more efficiently when storing and filling applications. [7]

Physical Load Consequences And Other Working Health Risks

In the European Union, around a third of all employees have to work with workloads daily and spend most of their working time there. Hand handling weights mean lifting, holding, carrying, storing or pulling heavy objects, either individually or by several employees at the same time. Manual handling of the weight can cause:

- *damage to health caused by constant and gradual deterioration of the skeleton and muscles* (e.g. lower back pain);
- *serious damage* (e.g. bone fractures; bruises or injuries caused by accidents).

MSDs reported as a work-related health problem form 60 % of all reported health problems. Thence, Backache as work-related health complaint was reported by 45.0 % male workers, Upper limbs muscular health problems by 44 % male workers, lower limbs problems report 30 %, one or more musculoskeletal disorders report 60 % of male workers. Females report similar but few percent less numbers. [4]
Manually handling the weight is dangerous due to several risk factors and increases the likelihood of injury. A handling task may pose a health risk if:

- we achieve it only with great physical effort; it is performed too often or for too long;
- it can be achieved only by turning the torso;
- may cause sudden movement of the weight;
- is performed with an uncertain or uncomfortable position of the body (including uncomfortable positions or movements, such as bending or rotating the body, lifting arms, bending the wrist, excessive load).

Working conditions may pose a health risk if:

- the available space is not sufficient for handling (especially in the vertical direction);
- the floor is unstable or slippery, which poses a risk of falling;
- handling work must be performed at different levels of the floor or surface;
- the soil is unstable;
- air temperature or humidity is not suitable for handling or ventilation is not required.

The heat makes employees sluggish and sweating makes it difficult to hold things in their hands - so employees need to use more force. Low temperatures can numb the hands, making it difficult to grip.

An employee's personal characteristics may pose a health risk if:

- the employee is not adequately trained in handling;
- the physical characteristics and abilities of the employee (e.g. height, weight, strength) are unsuitable for a specific task;
- The employee has previously had back problems.

The differentiation of the prevalence of MSDs by gender, age and level of education underlines that there is a need for diversity-sensitive approaches/risk assessments to better prevent and manage MSDs.

Exoskeletons – Features, Function

Difference between robotics and exoskeleton engineering application is that robotics application replaces human labor, while the exoskeleton is the mechanical application, often involves Robotics and Biomechatronics to expand human opportunities in performing various tasks. [7]

Generally Exoskeletons:

- are located on the user's body and act as amplifiers that increase, enhance or restore human performance. The opposite would be a mechanical prosthesis, such as a robotic arm or leg that replaces the original body part.
- can be made of rigid materials such as metal or carbon fibers, or they can be made entirely of soft and elastic parts.
- can be powered and equipped with sensors and controls, or they can be completely passive.
- can be mobile or fixed /suspended (usually for rehabilitation or teleoperation).
- can cover the whole body, only the upper or lower limbs or even a specific segment of the body, such as ankle.

Placing tools on a high shelf or occasionally replacing a component overhead may not be difficult, but imagine performing one of these tasks 4,600 times a day, or about 1 million times a year. This is the approximate number of car assembly line workers who raise their hands above their heads during working hours. At this rate, the likelihood of fatigue or injury to the body increases significantly. A new **wearable upper body tool** helps reduce the likelihood of injury (Fig. 1).

Fig. 1 Wearable upper body exoskeleton suitable for work overhead

Passive lower back exoskeleton supports static posture work as well as dynamic transfer activities of load manipulation through mechanical action on the body. If a person leaning forward is supported, the load is transferred to the thighs. This reduces the stress on the lower back. The stress on the lower back can be reduced with the help of the Laevo exoskeleton (Fig. 2).

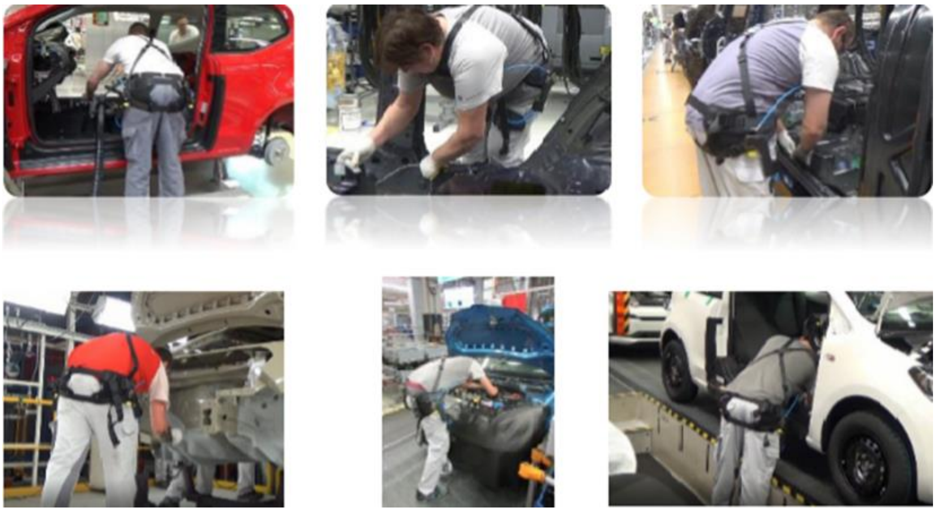


Fig. 2 Laevo exoskeleton in the testing phase in assembly operations

Chairless Chair enables employees to sit down even with short assembly intervals. Body weight is diverted into the floor via two adjustable elements. Enables work that is easy on the joints and back and improves posture. Preventive protection against back and knee problems and mostly positive feedback from employees is the intention.

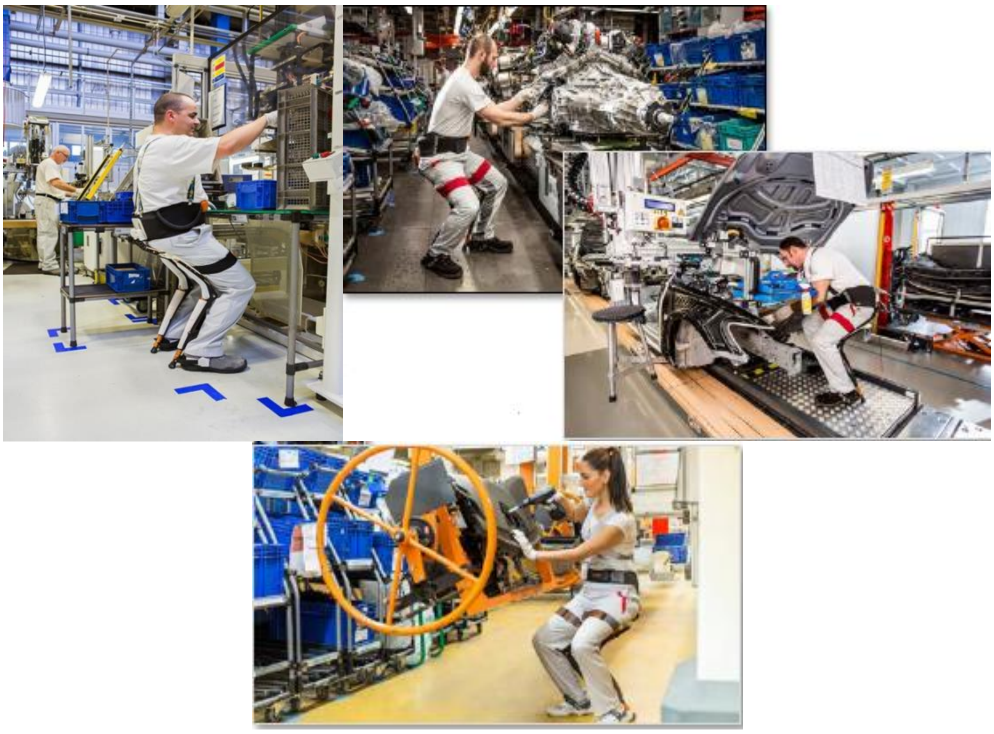


Fig. 3 Chairless chair exoskeleton in various working positions

Health effects are not yet recorded, neither positive nor negative. Therefore, carrying out scientific studies to verify the reduction in stress through the use of the Chairless Chair and other types of exoskeletons have to be performed, as well as definition of health exclusion criteria considered.

Conclusion

Most employees work in establishments that provide training on how to lift and move heavy loads and on how to properly use and adjust their employees’ equipment. Prevention of psychosocial risks is provided less. Other preventive ergonomic measures are rotation of tasks to reduce repetitive movements, regular breaks, provision of ergonomic equipment and provision of equipment to help lifting or moving.

The goal of performance-enhancing exoskeletons is to increase the strength and resilience of the human body and thus make laborious work easier for operators. These exoskeletons are not used for rehabilitation, but are used for healthy operators. The word "exoskeleton" literally means "outer skeleton." Today, exoskeletons can be defined as wearable devices that work with or without human commands. Advantages or their disadvantages and effects on human health are subject for further studies.

This work has been supported by the Applied Research and Development Agency APVV-19-0418 and Slovak Grant Agency KEGA 009TUKE-4/2020.

References

[1] BERLIN, C. – ADAMS, C.: Production Ergonomics: Designing Work Systems to Support Optimal Human Performance. London: Ubility Press, 2017, pp. 296.

[2] NATIONAL CENTRE OF HEALTH INFORMATION. Health Yearbook of Slovak Republic, Bratislava, 2019, ISBN 978-80-89292-71-4.

[3] EUROPEAN FOUNDATION FOR THE IMPROVEMENT OF LIVING AND WORKING CONDITIONS: Fourth European Working Conditions Survey. 2007.

[4] DE KOK, J., VROONHOF, P., SNIJDERS, J., ROULLIS, G., CLARKE M., PEEREBOOM, K., VAN DORST, P., ISUSI, I.: Work-related musculoskeletal disorders: prevalence, costs and demographics in the EUs. European Risk Observatory Report. European Agency For Safety And Health At Work (EU - OSHA), Luxembourg, 2019, ISSN 1831-9343.

[5] RUIZ-OLAYA, A.F., LOPEZ-DELIS, A., FERREIRADA ROCHA, A.: Handbook of Biomechatronics: Chapter Eight - Upper and Lower Extremity Exoskeletons. Academic Press, 2019, pp. 283-317, ISBN 978-0-12-812539-7.

[6] BOSCH, T., VAN ECK, J., KNITEL, K., DE LOOZE, M.: The effects of a passive exoskeleton on muscle activity, discomfort and endurance time in forward bending work. In: Applied Ergonomics. Vol. 54 (2014), ISSN 0003-6870, pp. 212 - 217.

[7] MARINOV, B. What is an exoskeleton? [online]. [cit.07.10.2020]. Available at: https://exoskeletonreport.com/what-is-an-exoskeleton/

[8] GRABOVAC, I. Ergonomic risks in sitting and standing workplaces. [online].[cit. 07.10.2020]. Available at: https://www.easom.eu/images/pdf/summerschools/summerschool17/Ivan_Grabovac-%20Ergonomic_risks_in_sitting_standing_workplaces.pdf

[9] BERTOLACCINI, G.D.S., CARVALHO FILHO, I.F.P.D., CHRISTOFOLETTI, G., PASCHOARELLI, L.C. AND MEDOLA, F.O.: The influence of axle position and the use of accessories on the activity of upper limb muscles during manual wheelchair propulsion. International Journal of Occupational Safety and Ergonomics, 24(2), 2018, pp.311-315.

[10] VIGNAIS, N., BERNARD, F., TOUVENOT, G. AND SAGOT, J.C.: Physical risk factors identification based on body sensor network combined to videotaping. Applied ergonomics, 65, 2017, pp.410-417.
[11] Internal materials of VW, a.s. company, Bratislava, 2019.

Contact address

Ing. Daniela Onofrejova, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: daniela.onofrejova@tuke.sk

Ing. Miroslav Agalarev
Volkswagen Slovakia, a.s., Industrial Engineering P1 – Ergonomist, Jana Jonasa 1, 843 02 Bratislava 49, Slovakia
e-mail: miroslav.agalarev@volkswagen.sk

Review process

Single-blind peer review process.

CLOUD-BASED DESIGN AND MANUFACTURING

Ivan ANTONIUK – Martin KRAJČOVIČ – Radovan SVITEK – Marián STÁREK

Abstract: Cloud-based design and manufacturing (CBDM) can be assigned to the service-oriented network product development model. In such a model, customers can change the configuration, select and use customized resources and services to realize products, whether it is computer software or a reconfigurable production system. The discussion surrounding CBDM can be divided into several aspects, such as definitions, basic characteristics, computer architectures, communication and collaboration, crowdsourcing processes, information and communication infrastructure, programming models, data storage and new business models related to CBDM. The article includes the definition of CBDM, the identification of basic characteristics and the definition of the list of CBDM requirements, and the comparison of CBDM with other relevant but more traditional collaborative designs and distributed manufacturing systems. such as web and agent design and manufacturing systems.
Keywords: CBDM, Crowdsourcing, Customer-oriented manufacturing.

Introduction

Cloud computing also uses technologies such as auxiliary computing, parallel computing, and virtualization, and therefore in the field of information technology (IT) it has proven to be a disruptive technology. Scalability, agility, elasticity, on-demand computing, and the provision of self-service services - these are its key features. Cloud design and production is adapted to the original paradigm of cloud computing and is introduced into the sphere of computer product development, thus gaining significant dynamics and attention from the academic and industrial spheres. CBDM is a network model of product development, meaning that service customers are allowed to configure, select, and use customized resources and services to implement products from CAE software to reconfigurable manufacturing systems.

Development of manufacturing systems

Due to changing market requirements and new technologies, production systems have undergone many significant changes [1]. Tab. 1 shows a brief evolution of production principles - from the assembly line, to Toyota production systems (TPS), to flexible production systems (FMS), to reconfigurable production systems (RMS), to web-based and agent-based production systems, and finally to Cloud-oriented production.

For example, Henry Ford created the first assembly line, which allows the gradual addition of replaceable parts to the product, then the finished products were produced more efficiently and cheaper. In the 1960s, TPS was designed to reduce production costs, also known as just- in- time production systems. TPS are characterized by several principles that help eliminate losses by reducing waiting time, inventory and the number of defective products. In the 1980s, FMSs were developed to provide new product variants, allowing a high degree of functional flexibility. The main advantage of FMS is that it allows the exchange of parts and assemblies, however, its implementation is usually expensive. According to [2], in order to quickly adapt production capacity and functionality within a component group in response to sudden market changes or regulatory requirements, design systems (RMS) are initially designed for rapid structural change as well as in hardware. and software components [2]. Key features of RMS include modularity, integrability, customization, convertibility, and diagnostics [3].

Tab. 1 Evolution of manufacturing systems [1]

Period	System	Configuration	Characteristics
1900th	Assembly line	Centralized	Reduced labor costs
			Increased speed of manufacturing
1960th	Toyota production system	Centralized	Reduced total production losses
			Reduced waiting times
			Reduced rejects
			Continuous improvement
1980th	Flexible production systems	Centralized	Reduced stocks
			Increased productivity
			Increased system reliability
			Increased diversity of production
			Increased utilization of machines
			A more flexible response to changes in production
1990th	Reconfigurable production systems	Centralized	Increased response to market changes
			Reduced time for product commissioning
			Shortened delivery time for the implementation of new production systems
			Rapid integration of new technologies
2000th	Web and agent-oriented production systems	Distributed	Improved information sharing
			Resource reusing
			Improved computing performance
			Remote monitoring and control
2010-present	Cloud-based manufacturing systems	Distributed	Reduced time to market
			Reduced costs
			Digital environment
			Joint production resources
			Improved information sharing
			Improved resource reusing
			Improved machine utilization

The production systems mentioned before belongs to the category of centralized production with significant changes in machine tools, plant layouts and business models. With the development of the Internet, industry is gradually expanding distributed manufacturing systems. The two main approaches to distributed manufacturing are web-based and agent-based manufacturing systems. Web systems use a client-server architecture along with the Internet and provide an easy platform for geographically dispersed teams to access and share production information through a web browser [4]. Similarly, with the increasing structural and functional complexity of web-based production systems, agent-based production systems focus on improving computing performance and agent-based communication [5]. Agent-based manufacturing systems consist of elements (such as manufacturing cells, machine tools, and robots) that exhibit autonomous and intelligent behaviors, such as search, reasoning, and learning. For example, an agent is an independent problem solver capable of making decisions by interacting with other agents and their environment [6].

Requirements for cloud-oriented design and production

Based on the characteristics of Cloud-oriented production systems, it is possible to derive a checklist of requirements that the design and production system should meet in order to belong to the area of Cloud-oriented production, and these are [9]:

- Providing of social media to promote communication, information and knowledge sharing in a network design and production environment.
- Providing of distributed cloud-based file systems that allow users ubiquitous access to design and production data.
- It should have an open programming framework that can process and analyze large data stored in the cloud.
- Providing of a multi-purpose environment where different software can be connected to each other and cooperate.
- It should be able to collect real-time data from production sources (eg machines, robots and assembly lines), store this data in the cloud, remotely monitor and manage these production sources.
- It should support users with a smart search tool to help them answer questions.
- It should provide a tool for pricing and generating immediate bids based on design and manufacturing specifications.

Communication

Improving communication in the design process is one of the ultimate goals of research in the field of engineering design. The design of any product is an integral part of the social and technical process. A key issue in improving design communication is the extent to which design engineers fully understand the complex design process, in particular the design tasks to be completed, the individuals from whom specific information can be accessed, the extent to which the information obtained is distorted, and the impact distorted information on design [10]. In traditional design, communication can be seen as a one-way process with a linear sequence of design phases, as shown in Figure 1 (a). Due to the use of social media in CBD settings, it is possible to improve design communication through multiple information channels (e.g., social networking sites and product control sites), in which information can flow in multiple directions, as shown in Figure 1 (b). [7]. For example, social media allows design engineers to work with customers simultaneously by obtaining immediate feedback from customers.

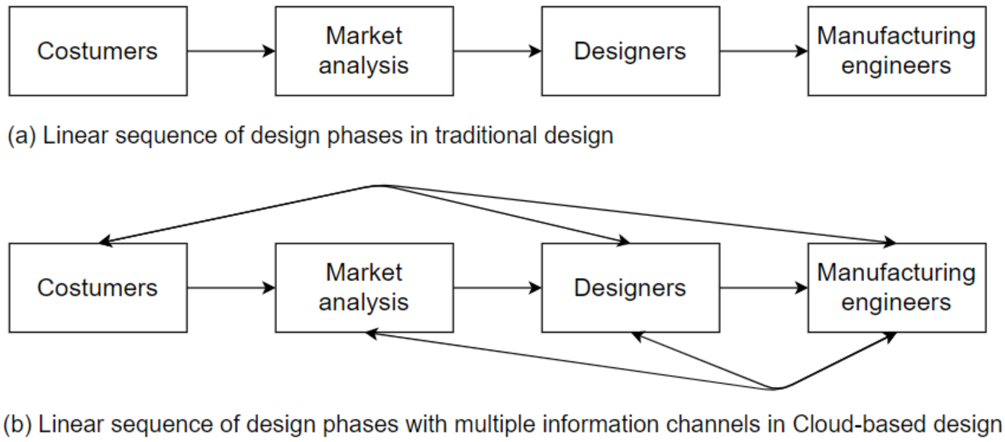


Fig. 1 Communication in designing process [7]

In addition, traditional computer-aided application tools (eg, CAD / CAE / CAM) were separate systems and designed for a single user without communicating and collaborating with others. In CBD settings, engineering design requires more communication and collaboration across organizations to model, analyze, and optimize design. The use of virtualization and multiple leasing in CBDM has the potential to enable concurrency with computer-aided design, engineering analysis, and manufacturing tools. In particular, computer-aided design, engineering analysis, and manufacturing tools in CBDM settings will allow users in an interdisciplinary design team to simultaneously create and modify structural elements of a product model. In addition, according to a recent survey, design engineers spend an average of 15% of their working time on the phone and receive an average of 50 emails per day. Communication tools (such as instant messaging, virtual meetings, screen sharing, and social networking sites) integrated into computer application tools enable multiple channels of information transfer, which can significantly increase productivity [8].

The process of obtaining resources in the context of CBDM

CBDM enables service consumers to quickly and easily find qualified service providers that offer design and manufacturing services such as CNC machining, plastic injection, casting or 3D printing through a cloud-based sourcing platform. Fig. 3 illustrates a cloud acquisition process that allows consumers to submit RFQs to a search engine and receive a list of qualified service providers.

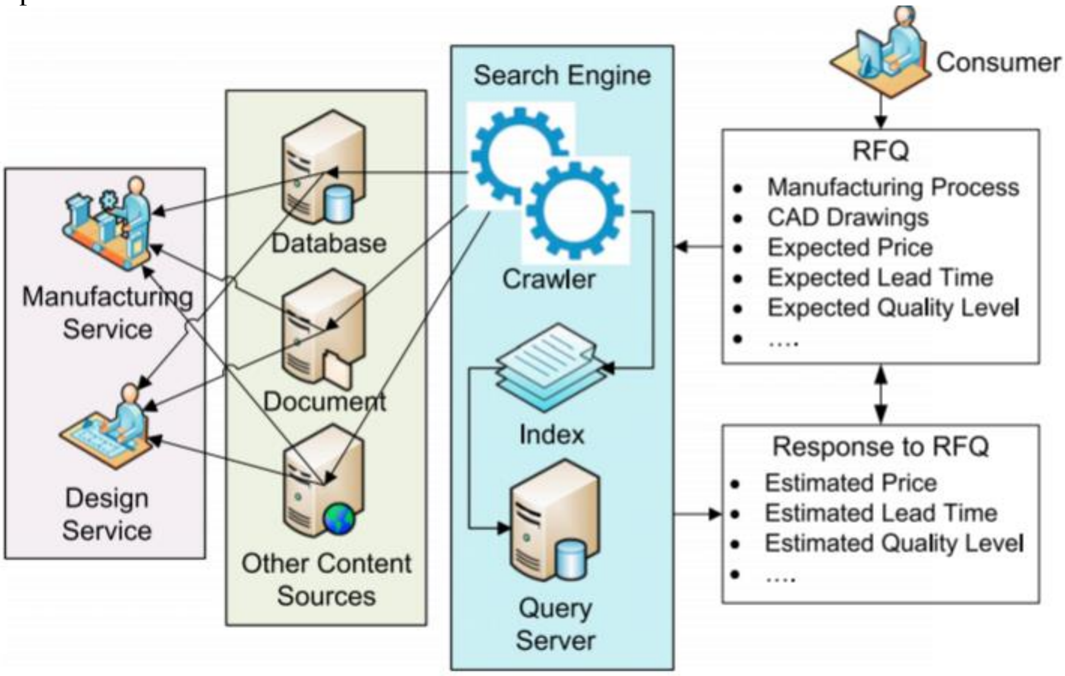


Fig. 2 Crowdsourcing process for RFQ in CBDM systems [8]

The search engine consists of a crawler, indexes, and query servers. The crawler collects production-related data (such as process variables, machine specifications) from databases, document servers, and other content sources and stores them in an index. The index sorts this data by metrics (e.g., price, quality, and geographic location) that users specify. The search appliance query server provides consumers with search query results in response to an RFQ. Results are based on specifications such as expected prices, lead times and quality levels. However, when it comes to web and agent-based design and manufacturing systems, it is not possible to implement such a computationally expensive sourcing platform that connects consumers and service providers around the world. Unlike existing 3D printing services, where users upload design files and print objects from a single location, CBDM allows users to print their designs to any 3D printer in the cloud, rather than to a specific location. [11]

Information and communication infrastructure

In terms of information and communication infrastructure, CBDM uses IoT (e.g., RFID), a smart sensor, and wireless devices (e.g., a smart phone) to collect real-time design and manufacturing data, as shown in Fig. 3.

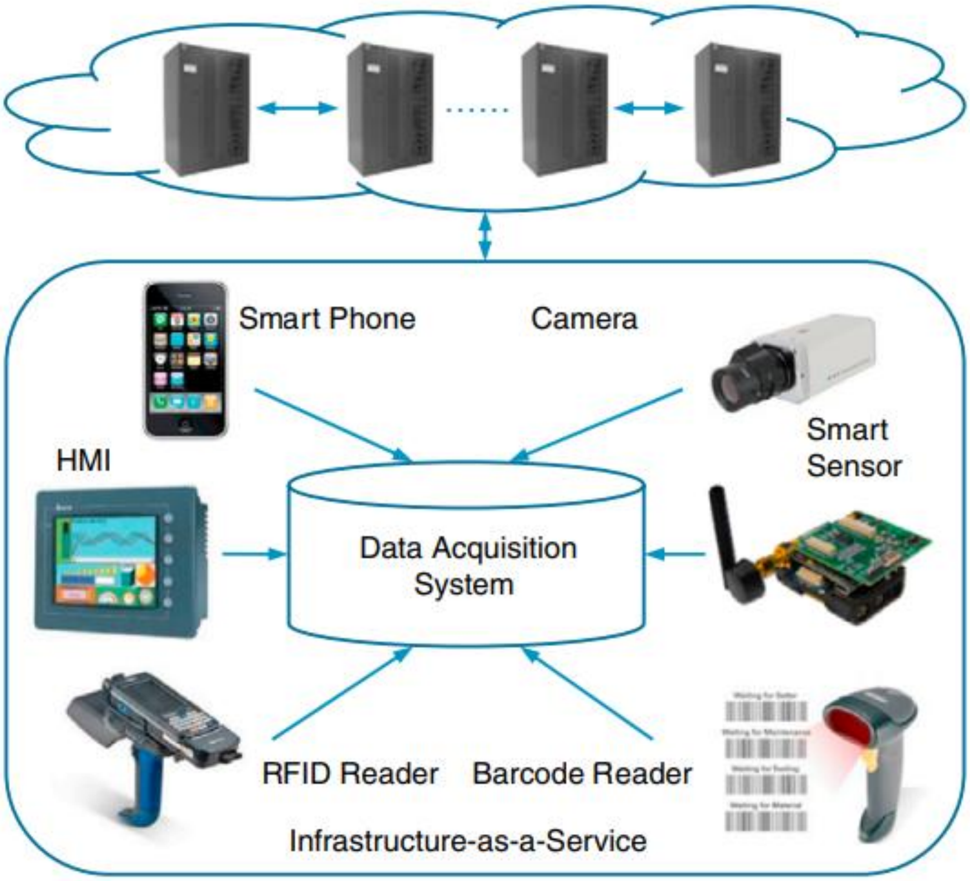


Fig. 3 Information and communication structure in CBDM systems [8]

The essence of IoT and built-in sensors is to capture events (eg. inventory levels), represent physical objects (eg. machine tools) in digital form and finally connect machines to people. For example, IoT allows engineers to access data such as machine usage, equipment conditions, and the percentage of defective products from anywhere. For large data generated by IoT-related devices, engineers can apply big data analytics for forecasting, proactive maintenance, and automation. However, such seamless connections cannot be provided in web-based design and manufacturing systems and agents due to their limited data acquisition and computing capabilities. [8]

Conclusion

In this paper, was discussed the definition for CBDM, identified common key characteristics, defined a checklist of requirements that any idealized CBDM system should meet, and compared CBDM with other relevant but more traditional collaborative designs and distributed manufacturing systems from several perspectives. In particular, CBDM is characterized by scalability, agility, high performance and affordable computing environments, network environments, ubiquitous access, self-service, big data, search tools, social media, real-time bidding, pay-per-use, pooling resources, virtualization, multi-use, crowdsourcing.

Acknowledgement: "This work was supported by the KEGA Agency under the contract no. KEGA 017ŽU-4/2019".

References

[1] TOLIO T., CEGLAREK D., ElMARAGHY HA., FISHER A., Hu SJ., LAPERRIERE L., et al.: SPECIES— co-evolution of products, processes and production systems. CIRP Ann 2010. pp. 715–733.
[2] Koren Y., Heisel U., Jovane F., Moriwaki T., Pritschow G., Ulsoy G., et al.: Reconfigurable manufacturing systems. CIRP Ann 1999.
[3] ElMARAGHY HA.: Flexible and reconfigurable manufacturing systems paradigms. Int J Flexible Manuf Syst 2005.
[4] FUSKO, M., BUČKOVÁ, M.: Digital models for auxiliary and service processes. In: InvEnt 2018: Industrial Engineering – Invention for Enterprise, p. (6-10). ISBN 978-80-89865-08-6.
[5] SHEN W., HAO Q., YOON HJ., NORRIE DH.: Applications of agent-based systems in intelligent manufacturing: an updated review. Adv Eng Inform 2006.
[6] FURMANN, R., FURMANNOVÁ, B.: Logistics and Digital Twin. In: InvEnt 2017: Industrial Engineering – Invention for Enterprise, p. (40-44). 2017, ISBN 978-83-947909-0-5.
[7] WU, D., SCHAEFER, D., ROSEN, DW.: Cloud-based design and manufacturing systems: a social network analysis. In: International conference on engineering design (ICED13), Seoul, Korea, 2013.
[8] WU, D., ROSEN., D. W., WANG, L., SCHAEFER, D.: Cloud-based design and manufacturing: A new paradigm in digital manufacturing and design innovation. Computer-Aided Design, 59, 1–14. 2015, doi:10.1016/j.cad.2014.07.006
[9] GREGOR, M., HODOŇ, R., BIŇASOVÁ, V., DULINA, Ľ., GAŠO, M.: Design of simulation-emulation logistics system. In: MM Science Journal. – Prague (Česko): MM publishing – No. 3 (2018), pp. 2498-2502. ISSN 1803-1269.
[10] TREBUŇA, P., PEKARČÍKOVÁ, M.: Mapping and modeling of internal business processes. In Intercathedra. No. 28/1 (2012), p. 91-95. ISSN 1640-3622
[11] IŽARÍKOVÁ, G., PEKARČÍKOVÁ, M., TREBUŇA, P., KRONOVÁ, J.: Comparative analysis of the industrial production inside the Euro zone. In Interdisciplinarity in Theory and Practice : the Journal for Presentation of Interdisciplinary Approaches in Various Fields. Arad (Romania) : Adoram č. 16 (2018), pp. 39-46 [print]. ISSN 2344-2409

Contact address

Ing. Ivan Antoniuk
University of Žilina, Faculty of Mechanical Engineering, Department of Industrial Engineering, Univerzitná 8215/1, 010 26 Žilina, Slovakia
e-mail: ivan.antoniuk@fstroj.uniza.sk

Review process

Single-blind peer review process.

MANUFACTURING EXECUTION SYSTEM OR INDUSTRIAL INTERNET OF THINGS FOR SMART MANUFACTURING

Miriam PEKARČÍKOVÁ – Michal DIC - Peter TREBUŇA

Abstract: This article deals with complexity of Manufacturing Operations Management compare to Industrial Internet of Things. To understand strategic advantages of the both systems and understanding how those system will change the way how we produce our products. Industrial Internet of Things is trying to disturb manufacturing automations standards as ISA-95 with new functionalities and different models in implementation. IIoT brings new way how to connect our shop floor and brings low cost solutions.
Keywords: manufacturing, internet of things, automatization, system

Introduction

Due to historical reasons, a large amount of the knowledge about production processes & coordination, machinery usage and ad hoc changes typically resides within workers' heads (tribal knowledge). Even if this information is captured, it is typically captured in disparate shop floor systems or in paper based processes. This information is difficult to access and when complemented with newer technologies, it is creating a counter-productive situation for manufacturers and production floor. With all the technological advancements happening in concept ideation, design & manufacturing engineering processes and production/automation technologies, production processes are challenged with unknown or un-validated “tribal knowledge”. This gap will be a bottleneck to be more competitive in market space. Early manufacturing considerations and process maturity should be complemented with meaningful information capture from production, specifically, shop floor events combined with product and process context. This information is of tremendous value to support continuous improvement initiatives. Data collected from shop-floor processes has impact and influence to many groups within an organization as shown below. The relevant shop-floor information coupled with context understandable to each target groups will enable the upstream processes to continuously improve and resolve issues way early in the process. Focused feedback from upstream engineering can streamline the production orchestration complexities with corrective actions and process adherence check points within shop-floor.

The Industrial Internet of Things (IIoT), Cloud and smart devices are bringing a new era in manufacturing. Creating a ‘Smart Factory’ or ‘Industry 4.0’ production model, they offer a way for the industry to stay ahead of the curve, producing increasingly sophisticated devices with greater efficiency and reliability than ever before. Does this mean a move away from manufacturing execution systems (MES) to a production model that only uses the IIoT? f MES is selected, does that mean systems will not use the power of IIoT?

The answer to all these questions is ‘No’. In fact, the answer to whether you should choose IIoT or MES is that, to get the best efficiency, agility and quality from your production facilities, you should have both.

Industrial Internet Of Things

The role of the IoT is becoming more prominent in enabling access to devices and machines, which in manufacturing systems , were hidden in well-designed silos. This evolution will allow the IT to penetrate further the digitized manufacturing systems. The IoT will connect the factory to a completely new range of applications, which run around the production. This could range from connecting the factory to the smart grid, sharing the production facility as a service or allowing more agility and flexibility within the production systems themselves. The evolutionary steps towards smart factory require enabling access to external stakeholders in order to interact with an IoT- enabled manufacturing system that is formed of connected industrial systems that communicate and coordinate their data analytics and actions to improve performance and efficiency and reduce or eliminate downtimes. These stakeolders could include the suppliers of the production tools (e.g. machines, robots), as well as the production logistics (e.g. material flow, supply chain management), and maintenance and re-tooling actors. The manufacturing services and applications do not need to be defined in an interwinded and stricly linked manner to the physical system, but rather run as services in a shared physical world. Some of the main challengges associated with the implemaentation of cyber-physical systems in include affordability, network integration and the interoperability of engineering systems. Most companies have a difficult time justifying risky, expensive and uncertain investments for smart manufacturing across the company and factory level. Changes to the structure, organization and culture of manufacturing occur slowly, which hinders technology integration. Pre-digital age control systems are infrequently replaced becaouse they are still serviceable. Retrofitting these existing plants with cyber-physical systems is difficuktand expensive.

Manufacturing Operations Management / Manufacturing Execution system

MES is designed to fulfill the needs of a broad manufacturing enterprise, by coupling front office accounting with the factory supervisory control systems and products. In addition to linking, MES also closely ties the outputs of these three layers of information systems those residing in the planning functions, such as MRP, execution functions, such as supervisory control software or quality control, and control systems that create the data utilized, so that the enterprise has full access to the separate databases of information that exist within the organization. MES’s functions such as scheduling, resource allocation, process management, quality management, and operation analysis, all operate to “translate” the real-time data occurring on the factory floor into information that is useful from a process control/management standpoint. This further ripples into other adjunct processes such as labor, equipment, and materials management; product tracking; and supportive systems such as quality and documentation.

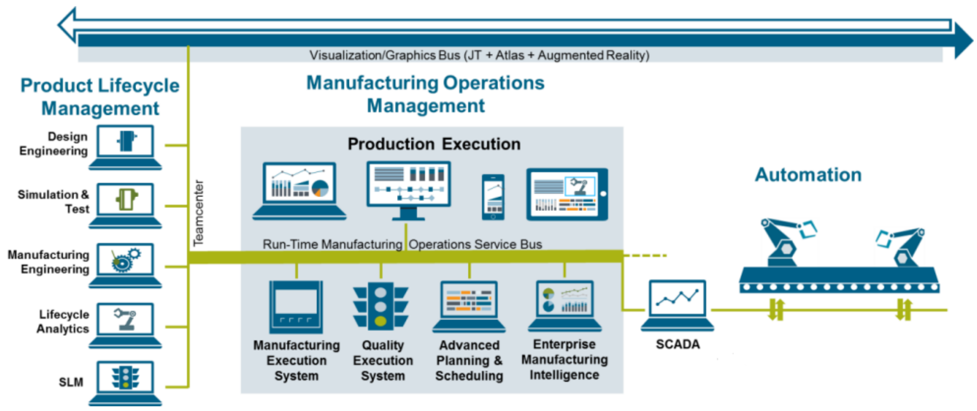


Figure Interaction of PLM, MOM and Automation

Fig. 1 Example of integration of Manufacturing operations system in Smart Manufacturing environment

Next level of Smart manufacturing

The forht industrial revulution, and hence the 4.0 will come about via the Internet of Things and the internet of services becoming integrated with the manufacturing environment.

The four main characteristics of Industry 4.0/ smart manufacturing

1. Vertical integration of smart production systems – factories are not designed on a standalone basis. There is a need for the networking of smart factories and smart production systems
2. Horizontal integration through global value chain network - Integration will facilitate the establishment and maintenance of networks that create and add value. The first relationship that comes to mind when we talk of horizontal integration is the one between the business partners and the customers.
3. Through-engineering across the entire value chain - The whole value chain in industry is subjected to what is termed through-engineering, where the complete l ifecycle of the product is traced from production to retirement.
4. Acceleration of manufacturing - Business operations, particularly those involved in manufacturing, make use of many technologies, most are not innovative or expensive, and most of them already exist.

In Smart Manufacturing environment, traditional understanding of MES, acting as a centrilized monolith between the ERP and shop floor automation don´t neccesarily fit with the use of distributed intelligence and the IIoT. This era of systems is coming to their end. It is important to have IioT connection capabilities within the MES which takes Smart manufacturing to the next leve. While sophisticated IioT platform can provide data aggregation, visualization and analysis, its bottom-up approach means it doesn´t see the wider perspective of manufacturing. Adding an MES solution that is implemented and designed to work within the IioT environment adds context and end-to-end process connections. This brings enablement of standardization, enforcement of quality processes and clearer visibility of events in supply chain.

Connection between IIoT and MES

- **Collaboration:** Modern MES can be understand as common information system for shop floor, not only throughout plant operations, but also across multiple facilities, suppliers ect. The key advantage is data consistency, enabling people or temas to work collaboratively and share data. Modern MES solution brings traceability of components on required level without any risk of data distortion.
- **Orchestration:** Even separate applications on an IIoT platform might carry out the required functions for smart manufacturing, an MES connect all these peices together for better optimization and operational outcomes.
- **Enforcement:** we can identify many different processes and procedures in standard production environment. Whether manual or automatic, machine or Robot or human – driven, a modern MES is able to controll all processes, policies, procedures and data correctly. An IIoT platform is not aware of the full breadth of operational activities covering all business processes (Sales, trainings, logistics, assembly, ect.)
- **Standardization:** IIoT environment might bring standardization to difficult level to achieve. In case of connection IIoT and MES, its enables workflows and processes to be roleld out easily and consistently. IIoT enables machine learning and is adding context which is provided by the MES so best practices can be clearly recognized and adopted to help increase engineering efficiency and enhance production performance.
- **Digital Twin:** We can understand MOM/MES solutions as digital twin of the plant and processes. This digital twin can be used as kind of the framework for dynamic activities between devices. Value-add and non-value-add production steps can be identified to help further tune of efficiency. With data about supply chain and business results, the digital twin creates environment whereby the plant can be fully optimized and business goals met. The digital twin also helps faculitate faster process introduction by providing rapid feedback and detailed information about production steps.

Conclusion

When we are talking about new era of production, Industry 4.0 or smart manufacturing, we are also talking about new era of production systems such as MES or IIoT. However, real distrubction is decentralization logic and new design which takes an IIoT production environment to new levels of efficiency. The future shop floor systems should be highly adaptable and configurable to specific and changing business needs. It needs to enforces, monitor and help continually with focus on improvement of existing manufacturing processes as dynamic environment. IIoT is one of the biggest leaps forward in last years of manufacturing technology. It brings many benefits and it cannot be ignored. Modern MES systems shoul be designed to realize these benefits, enabling and optimizing the transition to an IIoT environment.

Acknowledgement
This article was created by the implementation of the grant project APVV-17-0258 “Digital engineering elements application in innovation and optimization of production flows”, APVV-19-0418 “Intelligent solutions to enhance business innovation capability in the process of transforming them into smart businesses”, VEGA 1/0438/20 “Interaction of digital technologies to support software and hardware communication of the advanced production system platform” and KEGA 001TUKE-4/2020 “Modernizing Industrial Engineering education to Develop Existing Training Program Skills in a Specialized Laboratory.”

References

[1] VERMESAN O., FRIESS P., M,: Digitising the Industry - Internet of Things Connecting the Physical, Digital and Virtual Worlds, Riverpublishers, ISBN 978-87-93379-81-7
[2] GILCHRIST A. Industry 4.0 The industrial Internet of Things, Apress, ISBN 978-1-4842-2046-7
[3] TAO F., YHANG M., A.Y.C. NEE, Digital Twin driven Smart Manufacturing ISBN 978-0-12-817630-6
[4] JESCHKE S., BRECHER Ch., SONG H., RAWAT D.B., Industrial Internet of Things – Cybermanufacturing systems, Springer, ISBN 2365-4139
[5] Siemens DISW ebook – Manufacturing Operations Management - Software portfolio that helps you realize innovation in the Digital Enterprise
[7] MEHTA B.R., REDDY Y.J., Industrial Process Automation Systems – Design and Implementation, Elsevier, ISBN 978-0-12-8009390

Contact address

doc. Ing. Miriam Pekarčíková, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: miriam.pekarcikova@tuke.sk

Ing. Michal Dic
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: Michal.dic@gmail.com

prof. Ing. Peter Trebuňa, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: peter.trebuna@tuke.sk

Review process
Single-blind peer review process.

NEW APPROACHES IN THE DESIGN OF PRODUCTION AND LOGISTICS SYSTEMS

Olha KOLESNYK – Peter BUBENÍK – Miroslava BARBUŠOVÁ – ČAPEK Juraj

Abstract: Most small and medium-sized enterprises still use backward types of information technology and practice. To improve business logistics through the full use of state-of-the-art technology and policy, this document offers a multi-level cloud platform with computer system support for virtualization and logistics management, execution, real-time reconfiguration, and simultaneous and accurate process synchronization. industrial wear technology transforms traditional assets into cloud assets. In the cyber world, synchronization mechanisms improve the use of space and resources, while reducing expectations and waste. The platform is being implemented through two main pilot cases.
Keywords: Cyber-physical E-Commerce Logistics System, iCoordinator, Mobile Gateway Operating System.

Introduction

The new operating model requires the use of advanced system technologies. However, information technology and practices still lag in most small and medium-sized enterprises (SMEs) due to capital constraints and technical thresholds.
IT architecture and solutions lag: there is still a gap between the level of planning and decision-making and the level of implementation.

- The traditional method of data collection and interaction: operations involve intensive manual data collection on paper. Information is delayed, and sometimes even missing.
- Unsynchronized resource scheduling and order fulfillment: Unsynchronized sorting can limit storage space usage. Initial deliveries may take up limited space before waiting and waiting for the next items in the cache.
- Unstructured automation: A fully automated solution is usually capital-intensive and equipped with state-of-the-art robotics and equipment.

Several state-of-the-art technologies can be used to facilitate flexible business management. A cyber-physical system (CPS) is defined as a transformation technology for managing interconnected systems between its physical assets and computing power. Human-centered activities in cyber-physical production are developed, modeled, and evaluated to improve the overall productivity and organization of the plant.

The cyber-physical architecture of logistics e-commerce system

Based on CPS technologies, it develops the structure of the Unified Cyber-physical E - Commerce Logistics System (CPeLS) from real-time field data collection, through heterogeneous coordination and resource planning to optimal supply chain synchronization solutions [1].
The common platform is built on a cloud architecture that provides three levels of cloud service: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) in Fig. 1. Which provides systematic integration, deployment, and sharing of several technologies at logical levels. The implementation of corporate information systems that meet this standard hierarchy will ensure the suitability and expansion of the system for companies. Seamless two-way connectivity and real-time compatibility can be achieved between enterprise, workstation, workstation, and IoT application systems. The approach to creating

a CPS-enabled business logistics platform is generally applicable when other management standards, strategies or facilities are adopted, whether they replace or complement existing solutions [1].

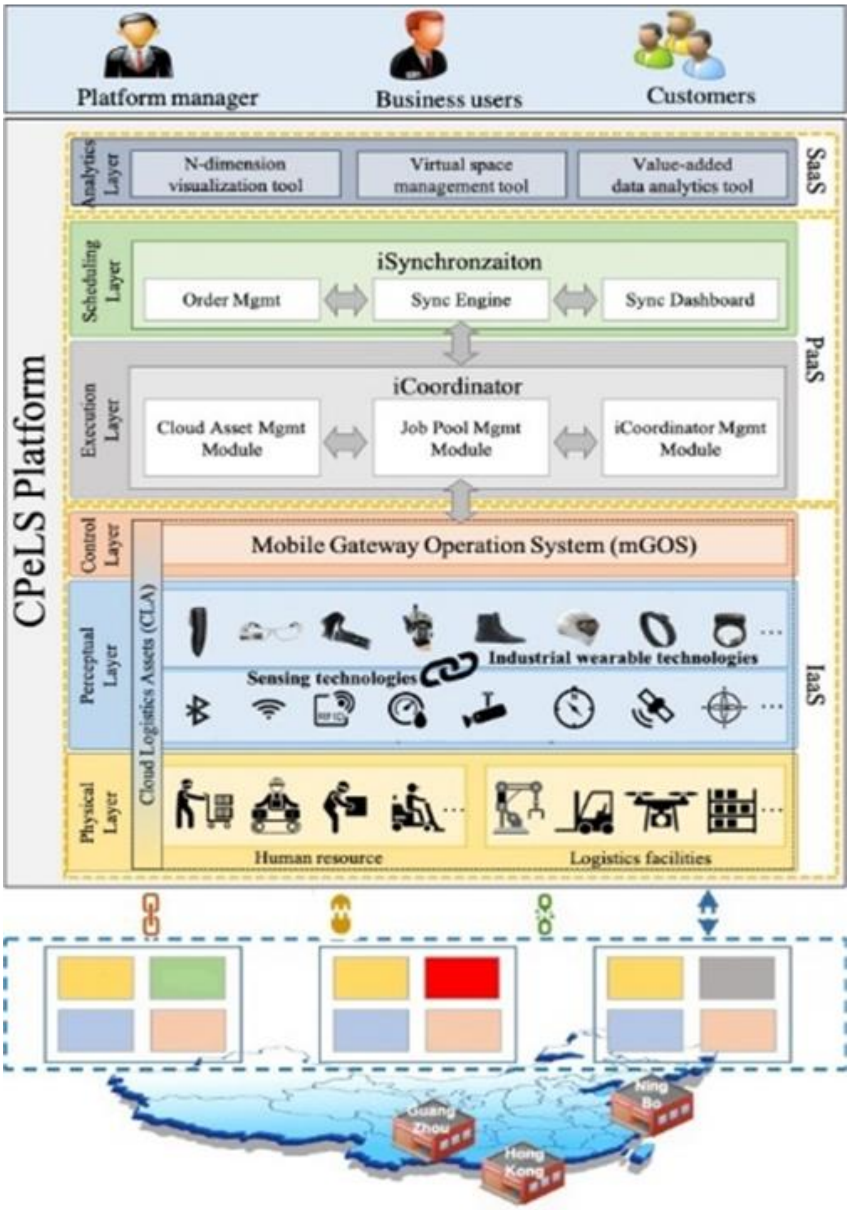


Fig. 1 General architecture of the logistics platform with CPS enabled [1]

At the IaaS level, cloud logistics asset (CLA) is the core technology for converting physical logistics assets into virtualized cloud agents. The main element of the CLA is the Industrial Wearable Object (IWO), which combines sensor technology and industrial wearables. MGOS (Mobile Gateway Operating System) is another key technology for achieving virtualization of physical resources and for the implementation of intelligent management in the software aspect [2].
At the PaaS level, the following two key components are included: 1 - intelligent coordination system (iCoordinator), as the main technology at the implementation level, facilitates the execution of a synchronized order fulfilment process; 2 - intelligent synchronization system

(iSync), which works at the planning level, is designed to solve synchronization problems in the logistics parks of the store [2].
At the SaaS level, three services are included: 1 - various stakeholders provide a multidimensional visualization tool to control relevant synchronization information; 2 - cyberspace management tool includes the concept of "virtual enterprise" and coordinates different business logistics scenarios in distributed geographical areas with different business goals. CPeLS using standardized and open application programming interfaces. CPeLS also separates the operating environment for deploying prepaid services and provides a secure cloud for enterprise users. Third, the value-added data analysis tool preserves theoretical and empirical models for optimizing supply-side and demand-side processes [2].
To ensure data security, all API calls in the proposed system must process authentication. It can dynamically issue certificates to users, allowing them to enter the active directory environment as if they had a smart card. In addition, information labels should be used so that the system can recognize the level of sensitivity of the data when used as outgoing messages [3].

iCoordinator for intelligent operations
Many of the implemented examples are based on innovative CLA technologies. Thanks to the real working environment in the e-commerce logistics fleet, three typical operations with CLA support have been created, including intelligent caching, intelligent patrolling and intelligent consolidation. iCoordinator will provide touch compatibility of these intelligent operations [3].

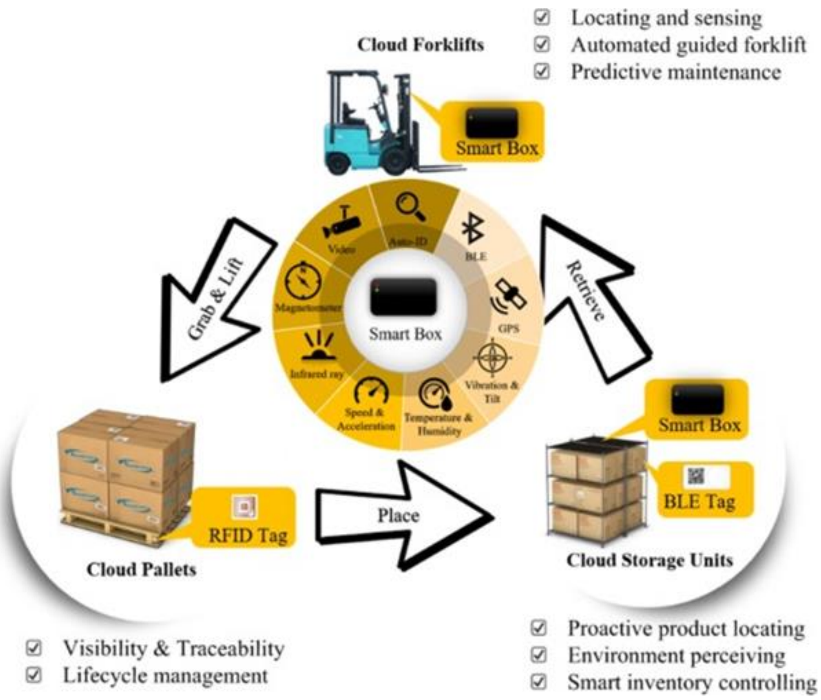


Fig. 2 Smart caching with CLA support [3]

Intelligent buffering determines the operational process of internal movement of stored goods from a specific storage location to another storage location by loaders. This operation involves various assets, such as pallets, forklifts, shelves and racks. At present, these assets operate independently and are difficult to manage. Intelligent caching consists of three main components: cloud loaders, cloud pallets, and cloud storage. Intelligent caching makes physical assets smart because they can be perceived by others and perceived by those around them. [4]

iCoordinator performs two main functions, as shown in Fig. 2. On the one hand, it handles service requests from iSync at a higher cloud level. On the other hand, it collects and distributes real-time notifications from different types of CLAs through intelligent consolidation, caching, and patrol operations [4].

InSync for intelligent processes

InSync is responsible for developing optimal task distribution plans and local work and process plans in stores using advanced mathematical models or solution algorithms. Key users can be managers, designers, and planners. As shown in Fig. 3, iSync includes delivery synchronization, transaction synchronization, and order synchronization that correspond to the delivery process, the warehouse consolidation process, and the delivery process. Different users can use special synchronization tools and user-friendly interfaces to perform their daily operations and decision-making. The developed operating mechanisms and optimization methods correspond to all these synchronization scenarios [5].

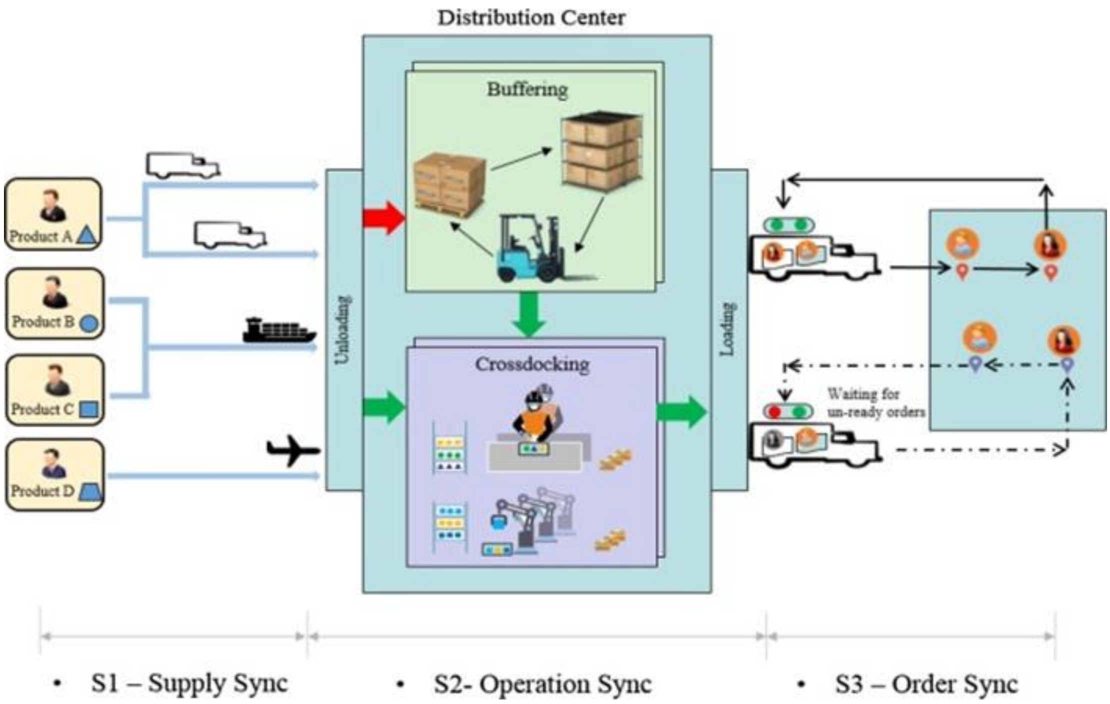


Fig.3 General synchronization scenarios in the e-commerce logistics park [5]

Conclusion

Cloud logistics assets that are subject to industrial transformation transform the company's traditional logistics assets into intelligent agents with real-time scanning, communication, and recognition functions. mGOS also provides tools for managing the (re) configuration of these decentralized collaboration tools.

The CPeLS platform implements the modularization of technological applications. All the proposed technologies are integrated into a systematic platform that can be easily and quickly accessed by different users.

To continuously improve the CPeLS platform, it is recommended to conduct future research in several aspects. First, in addition to technical improvements, it must create an efficient and effective business model. Gaming theory-based approaches to revenue management should be explored, considering the preferences of different stakeholders in e-commerce logistics chains.

Second, during the implementation of the platform, you can capture and collect a huge amount of data on transactions and transactions. Such data contains a wealth of implicit information and knowledge that advanced technologies, such as Big Data Analytics, require the provision of management information and practical guidance in real life. Finally, the impact of the new policies and regulations on the CPeLS platform is also extraordinary.

Acknowledgments: "This work was supported by the KEGA Agency under the contract no. KEGA 022ŽU-4/2018”.

References

[1] BAHETI, R., & GILL, H. Cyber-physical systems. Influence of control technology, 12 (1), 161–166. 2011.
[2] CHEN, J., HUANG, GQ, LUO, H., & WANG, J. Synchronization of production and shipment planning in the assembly flow. International Journal of Industrial Research, 53 (9), 2787–2802. 2015.
[3] FUSKO M., et al.: Concept of long-term sustainable intralogistics in plastic recycling factory, In: Sustainability Vol. 11, No. 23 (2019), ISSN 2071-1050
[4] BUČKOVÁ M.: Smart factory and manufacturing. In: Advanced industrial engineering, Bielsku-Białej, 2019. - ISBN 978-83-66249-29-5.
[5] TREBUŇA, P., PEKARČÍKOVÁ, M., KLIMENT, M., TROJAN, J., MIZERÁK, M. 2019. Modelling and simulation of production systems in industrial and digital engineering. 1. vyd. Lüdenscheid : RAM-Verlag 2019. 441 s. [print]. ISBN 9783942303927.

Contact address

Ing. Olha Kolesnyk
University of Zilina, Faculty of Mechanical Engineering, Department of Industrial Engineering, Univerzitná 8215/1, 010 26 Žilina, Slovakia
e-mail: olha.kolesnyk@fstroj.uniza.sk

Review process

Single-blind peer review process.

EVALUATION OF PRODUCTION WORKER UTILIZATION WITH A DIGITAL PARAMETRIC MODEL

Radovan SVITEK – Martin KRAJČOVIČ – Ivan ANTONIUK – Marián STAREK

Abstract: The plants are primarily focused on increasing the efficiency of internal processes. The management of production plants therefore needs to know a realistic picture of their current state, risks and opportunities, so that the plant's presence on the market is not jeopardized and they are able to effectively manage internal and external processes. All this will be possible only through the implementation of new technologies and the transformation of existing factories through digitization. This combination must be based on the scheduling currently provided by interactive software scheduling systems. The article deals with the area of using a software solution for interactive evaluation and capacity sizing of production workers.
Keywords: Industrial Engineering, Digital Factory, Software Solutions.

Introduction

In current industrial practice, innovative solutions are proposed to improve production and assembly processes or entire production or logistics systems [1]. To implement new technologies, companies must be able to combine the use of the latest and most available technologies. The smart solution in the field of production design and evaluation, which corresponds to current industry trends and the Industry 4.0 concept, is the software known as CEIT Table.

Recently, great emphasis has been placed on the development of functions in the field of capacity planning of production workers. Based on these functions, the user is allowed to create a parametric model of production with a link to individual work tasks. When changing the production volume, production technology, measuring or setting procedures, the workloads of individual work positions are recalculated.

Defining current problems of production plants.

Management in the capacity sizing of production workers lacks data, information, methods and tools for clear evaluation. The problem is that planning is based on principles that have been in use for more than a hundred years. In companies, many data in electronic form (about 60%) is a problem, however, that the data do not form structural units that could be used for capacity dimensioning and evaluation of production workload.

Some data (approximately 40 %) are collected and evaluated at one-day intervals and stored in paper form, operatively used to identify production problems stored in company archives. Their use is very laborious and time consuming.

At present, companies also lack a unified software solution for detailed capacity sizing of employees, which would be based on data from production processes, linked to specific activities of the production process (absence of digital data model of production). The combination of long-defined principles of capacity planning with digitization brings a completely new quality of data necessary for decision-making [2].

The paper deals with own research in the field of using a software tool for capacity sizing of production workers (creation of a parametric data model of production) and evaluation of production disposition. The research is carried out in a company engaged in the production of automotive components. Among the current problems related to the capacity dimensioning of production workers after the analysis of the current state in the company, we include:

- Inaccurate planning due to inaccurate or incomplete data.
- Missing or inconsistent software and evaluation rules, shortcomings in the information flow.
- Human mistakes resulting from an insufficient system of work, missing rules, motivation.
- Oversized, undersized capacities (workers, handling equipment, areas).
- Problematic data acquisition, insufficient validity, and outdated data.
- Undefined valid regulations or only partially, missing regulations, insufficient overview of the flow of information.

How to solve the problem.

Best methodological procedures, which were at a high level, were supplemented by new technologies (algorithms) for processing data structures for the needs of capacitive dimensioning. Evaluation and planning of production capacities consists in collecting information, processing them, creating analyzes, finding the best design and its verification. It is a classic methodological procedure, but new technological possibilities give it a completely different dimension and added value [3, 4]. A digital data copy of a real system is analyzed with the help of a software tool easier (from the point of view of labor, the possibility to make a change, etc.) than this analysis would have been done in the past.

CEIT Table software was used for the solution, which was the subject of research in the previous activity. Capacitive dimensioning in the software consists at the very beginning in the processing of input data. The basic input data needed for the analysis of the capacity utilization of workers can be divided into the following categories, data directly related to the machinery:

- Regular activities (activities related to the volume of production).
  - Loading / unloading on a belt, directly into the machine with workpiece clamping, on a pallet.
- Visual inspection of part machining.
  - Semi regular activities (semi - regular activities).
  - After a certain number of pieces, check the sample (hardening process, etc.).
- Irregular activities (activities that do not change with the volume of production).
  - Service activities at the workplace, cleaning, morning consultation with the manager.
- SMED activity (proportion of sorting time per change).
- Autonomous maintenance activities (share of maintenance time per change) [7, 8].

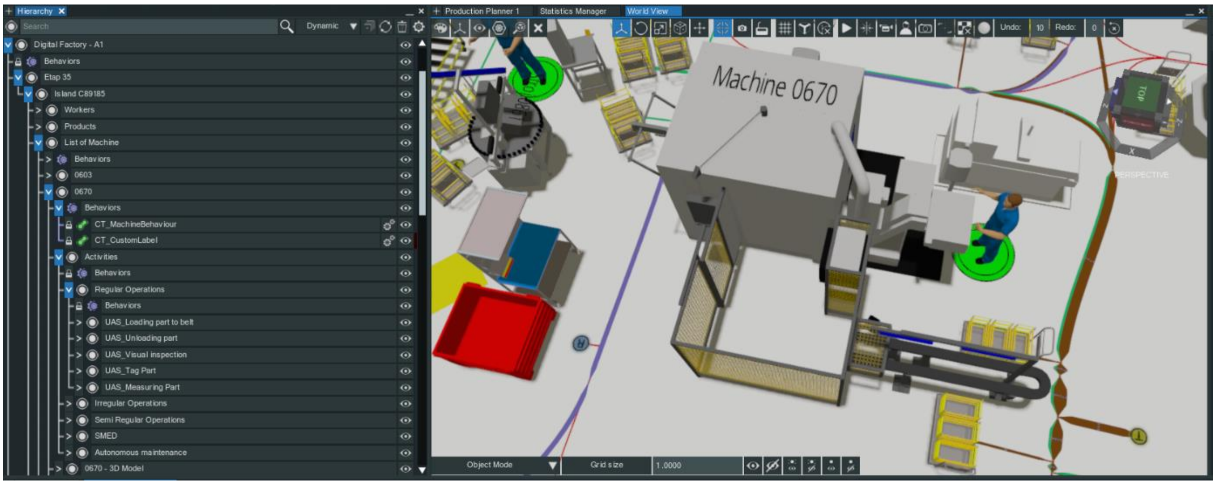


Fig. 7 Hierarchy of assembled digital model of production disposition [Source: Authors, 2020]

The creation of a data model of the production system takes place based on the current state, automatic import of data or their manual insertion. After entering and hierarchical assignment of all data Fig. 1, the calculation takes place in the background and its constant updating. Mathematical algorithms connect the structures of individual input data and generate output data using established rules, from which output analyzes of capacity utilization of production workers are created.
From the collected data, a digital data model is created in the software environment, which is supplemented by a 3D Fig. 2 representation of the production space for a better perception of the interconnections of some data and data structures.

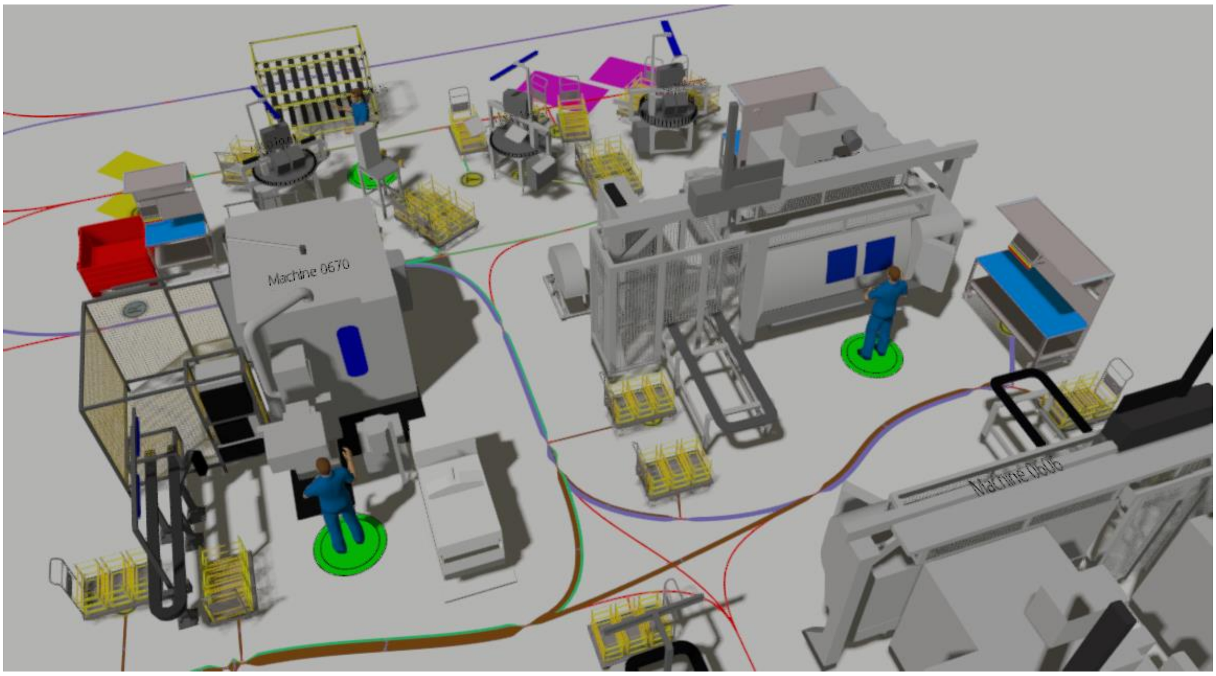


Fig. 8 Virtual representation of production space in a software environment
[Source: Authors, 2020]

Based on the creation of a digital representation of individual work tasks (with a defined time intensity), it is possible to assign them in the software to job positions on the basis of a technological process, or the knowledge of production managers [5, 6]. It is then possible to quantify the amount of capacity required for multi-machine operation or to evaluate the uneven capacity utilization of production personnel.
After changing any input parameter of the digital data model of production, the created links are recalculated in the software and the user has an up-to-date overview of the impact of the entered changes. The basic parameter that influences the change in the workload of production workers is the production quantity of individual products just determined (Fig. 3).

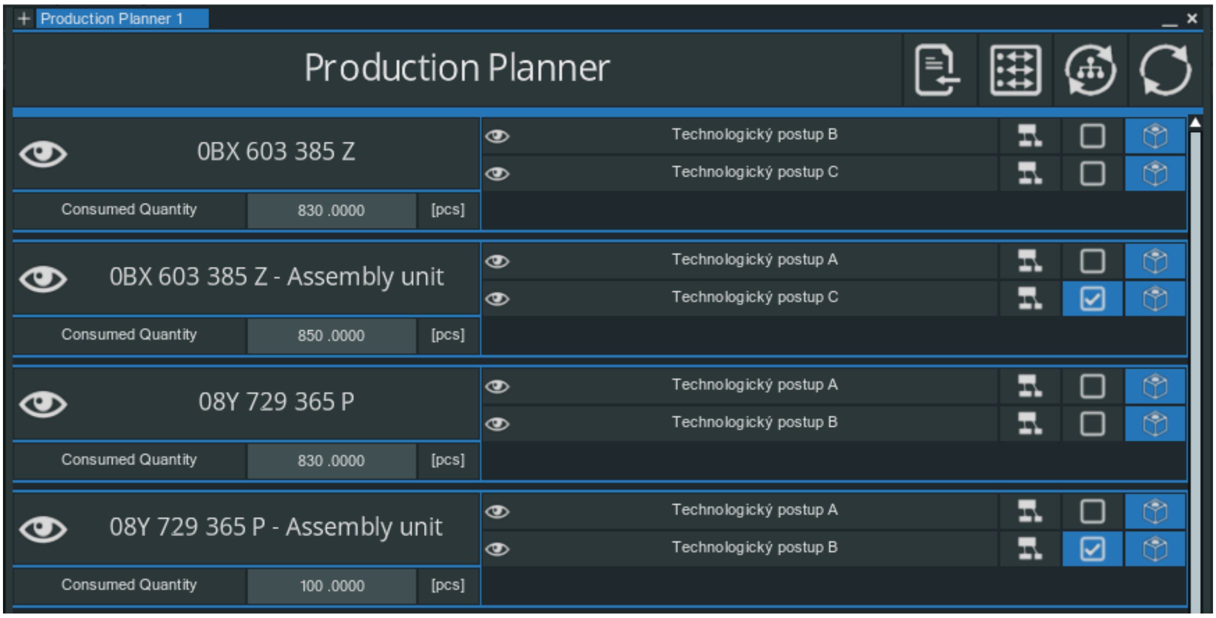


Fig. 9 Overview of produced quantities of individual product groups
[Source: Authors, 2020]

Evaluation of the results of practical application

At the production stage, the production workers have the task of machining the supplied raw material in the form of a forging into the form of a finished customer component, which will serve as an input to the assembly of the engine or gearbox.

Manufacturing operations are divided into individual points according to the nature of machining, starting with hard turning and ending with thermo-chemical surface treatment of the machined component.

Workers have prescribed tasks that ensure the smooth running of production. These are measuring operations according to established test procedures. Tool change, subject to adjustment, based on a delta of machining tools. Operations related to the regular inspection of machine parts or operating fluids in the form of prescribed work procedures.

With the help of the tool, we created several variants of the layout of prescribed production operations for individual job positions / workers.

After making any change, the system interactively evaluated the impact and recalculated the resulting parameters of the required capacity of the personnel of the proposed production system. The production system has changed:

- Distribution of operations evenly on individual employees according to the analyzed time consumption of the given operations using the MTM UAS methodology.
- Number of individual workers at individual production workplaces.
- Installation of workplaces (Fig. 2), placement of material entering the assembly in range zones up to 3 [m] (prevention of losses caused by walking).
- Replacement of machinery, more modern design, automated some operations, automatic detection of material defects after processing.
- Inter-operational manipulation at individual workplaces, use of drop conveyors, storage conveyors, etc.

The results of the analyzes confirmed the above-mentioned problems with the capacity dimensioning of production workers (by creating a parametric data model of production) and the evaluation of production disposition.

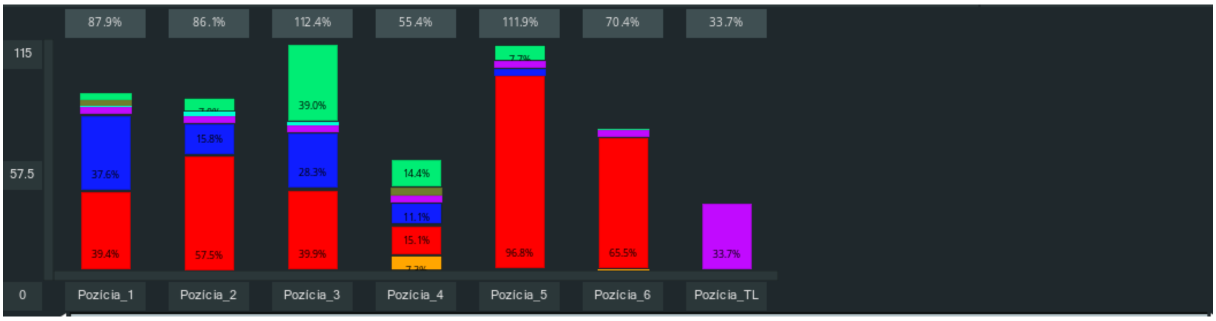


Fig. 10 Capacity utilization of employees by prescribed activities in valid documentation [Source: Authors, 2020]

There is a discrepancy between the software evaluation see Fig. 4 and the opinion (expert judgment based on experience) of the production capacity planning officer. After the presentation of all input data, the opinion is concluded that there are still activities that are not prescribed by the valid documentation or are not clearly quantified in terms of frequency / duration. Tab. 1 shows an example, the analysis of the capacity utilization of the workers of the production stage by the activities defined by the valid documentation. Subsequently, an increase in capacity utilization by activities that do not have a valid agreed regulation (valid documentation), but from the point of view of the process are necessary to maintain the quality set by the customer (absent in the calculation, it is generating a loss of 28.9% of production staff capacity).

Tab. 5 Analysis of capacity utilization of production workers [Source: Authors, 2020]

Rankings:	According to the documentation [%]:	At the discretion of TL [%]:	Difference [%]:
Person 1	87,9	90,0	2,1
Person 2	86,1	86,1	0
Person 3	112,4	112,4	0
Person 4	55,4	82,2	26,8
Person 5	111,9	111,9	0
Person 6	70,4	70,4	0
Person TL	33,7	33,7	0
		Sum:	28,9

Distribution of individual production operations based on the analysis of them time consumption allowed us to more optimally distribute the tasks (Fig. 5) of job positions (Fig. 6) and thus more evenly utilize individual production workers.

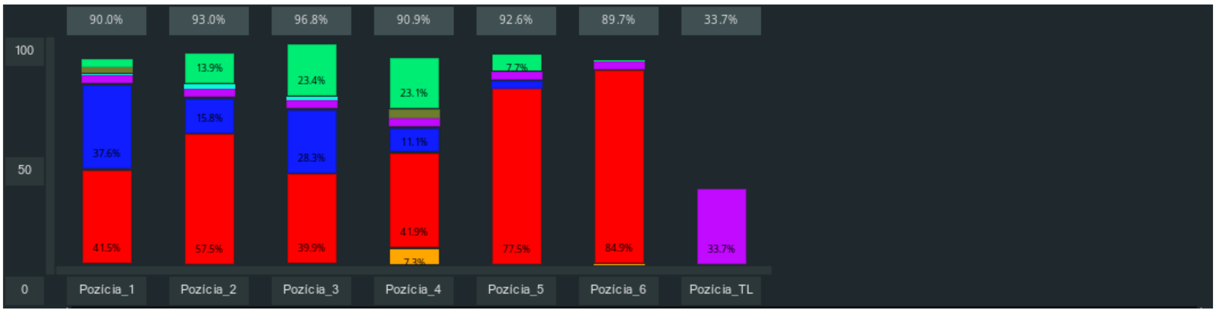


Fig. 11 Utilization of employees capacities by activities without valid documentation [Source: Authors, 2020]

Together with the elimination of waste in the form of: walking between machines, unstable machinery, or incorrect redistribution of mandatory tasks, the proposed changes found that the need for production workers at a particular stage is two less than the number actually allocated for production (personnel records – nine employees). This represents a significant saving (22 % reduction) in terms of staffing needs.

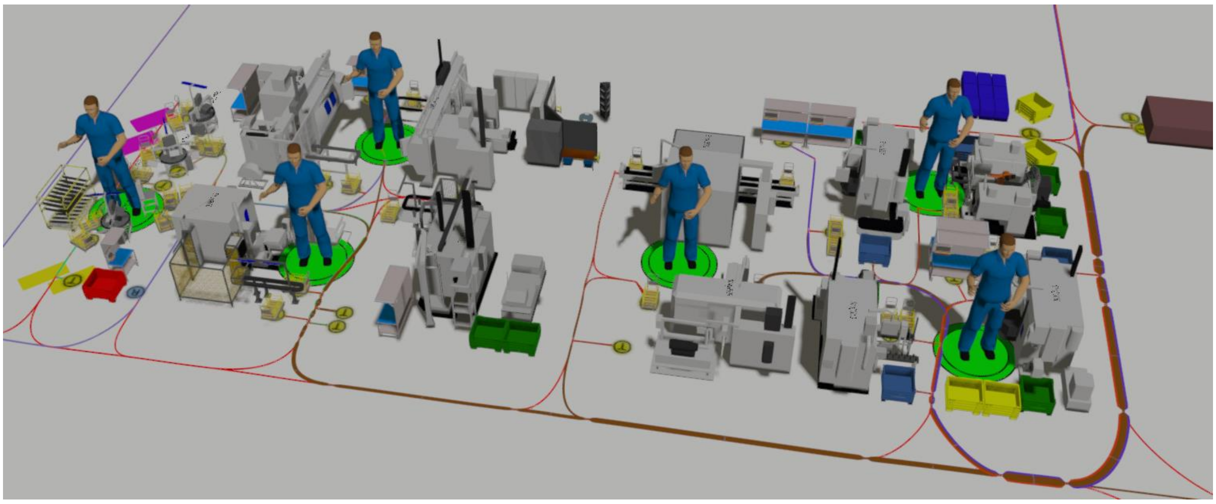


Fig. 12 Illustrative filling of individual job positions in production (without TL)
[Source: Authors, 2020]

Based on the mentioned changes and research in this area, it is possible to design production workplaces and capacity utilization of workers more optimally. With the help of a software solution, it is possible to reveal a significant potential for the redesign of existing production systems.

Conclusion

New functionalities of software solutions are now necessary in creating and evaluating the design of complex production structures. Software solutions that encourage mutual communication and interaction of individual system objects offer an effective tool for creating a design, which can then be changed without demanding changes to each element of the system. Thus, a supportive design tool with interconnected and communicating elements can provide information and feedback in the process of creating change for further decision-making of industry organizations. It helps to reveal a discrepancy between the design and reality, quantifies the difference, helps to reduce unnecessary losses of the production company.

Acknowledgement: "This work was supported by the Slovak Research and Development Agency under the contract No. APVV-16-0488”.

References

[1] GREGOR, M., HODOŇ, R., BIŇASOVÁ, V., DULINA, Ľ., GAŠO, M.: Design of simulation-emulation logistics system. In: MM Science Journal. – Prague (Czechia): MM publishing – No. 3 (2018), pp. 2498-2502. ISSN 1803-1269.
[2] MIEBACH, J., MÜLLER, P.: Intralogistik – Potentiale, Perspektiven, Prognosen. Springer, Berlin, Heidelberg, Germany, 2006. ISBN 978-3-540-29657-7.

[3] FUSKO, M., BUČKOVÁ, M.: Digital models for auxiliary and service processes. In: InvEnt 2018: Industrial Engineering – Invention for Enterprise, pp. 6-10. ISBN 978-80-89865-08-6.
[4] FURMANN, R., FURMANNOVÁ, B., 2017. Logistics and Digital Twin. In: InvEnt 2017: Industrial Engineering – Invention for Enterprise, p. (40-44). ISBN 978-83-947909-0-5.
[5] CEIT Table. CEIT Table ver. 3.2.1. – technical documentation (User manual). Company CEIT a.s., 2019, p. 129.
[6] TREBUŇA, P., PEKARČÍKOVÁ, M., KLIMENT, M., TROJAN, J., MIZERÁK, M. 2019. Modelling and simulation of production systems in industrial and digital engineering. 1. vyd. Lüdenscheid : RAM-Verlag 2019. 441 s. [print]. ISBN 9783942303927.
[7] PEKARČÍKOVÁ, M., TREBUŇA, P. 2011. Trend in design of dismantling workplace. In Intercathedra. Vol. 8, no. 27 (2011), p. 65-68. ISSN 1640-3622
[8] PEKARČÍKOVÁ, M., TREBUŇA, P., MARKOVIČ, J. Time structure optimization of logistics chain during assembly. In American Journal of Mechanical Engineering. Vol. 2, no. 7 (2014), p. 262-264. ISSN 2328-4102

Contact address

Ing. Radovan Svitek
University of Žilina, Faculty of Mechanical Engineering, Department of Industrial Engineering, Univerzitná 8215/1, 010 26 Žilina, Slovakia
e-mail: radovan.svitek@fstroj.uniza.sk

Review process

Single-blind peer review process.

NÁVRH A IMPLEMENTÁCIA OPTIMALIZÁCIE PRACOVISKA NA VÝROBU ELEKTROMOTOROV

Michal SASIADEK – Jozef TROJAN – Marek MIZERÁK – Ladislav ROSOCHA

Abstract: Digitálna budúcnosť priemyslu je jedna z najnaliehavejších tém vo svete, aj na Slovensku. Digitalizácia otvára výrobným továrňam nové príležitosti pre zrýchlenie a zefektívnenie výroby. Úlohou človeka je zabezpečiť zodpovednú “inteligentnú” infraštruktúru na novodobé požiadavky. Preto je dôležité porozumieť vplyvu digitalizácie na podnikanie firiem či na ekonomiku, vplyvu inteligentných technológií na okolité prostredie a jednotlivé procesy. Digitalizácia zásadne ovplyvní ako budeme v budúcnosti vyrábať produkty a ako budú vyzerať energetické siete, ale prinesie aj zásadné ekonomické a sociálne zmeny. S pomocou nástroja Tecnomatix Process Simulate budeme modelovať, analyzovať a verifikovať procesy na úrovni výrobnej továrne až na úroveň výrobných liniek a pracovných staníc. V modeli budú zakomponované inteligentné prvky konceptu „Priemysel 4.0“.

Keywords: automatizácia, digitalizácia, Priemysel 4.0, Tecnomatix

Úvod

V súčasnosti priemyselná výroba prechádza významnou transformáciou, čo sa týka spôsobu, akým vyrábame výrobky - vďaka digitalizácii výroby. Tento prechod predstavuje autonómnu automatizáciu v priemyselných procesoch, a označuje sa ako Priemysel 4.0, ktorý predstavuje štvrtú revolúciu, ku ktorej došlo vo výrobe.

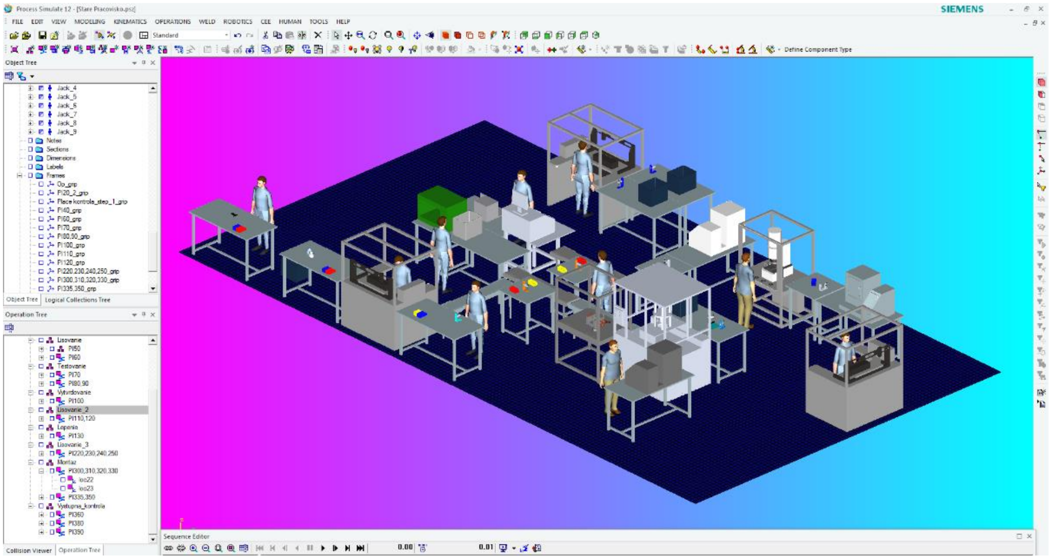
Priemysel 4.0 prináša to, čo sa nazýva "inteligentná továreň", v ktorom kybernetické fyzické systémy monitorujú fyzické procesy továrne a robia decentralizované rozhodnutia. Fyzické systémy sa stávajú internetom vecí, komunikujú a spolupracujú navzájom aj s ľuďmi v reálnom čase prostredníctvom bezdrôtového webu [1], [2].

Industry 4.0 je prechodom, ktorý je založený na dátovej a automatizačnej technológii, ktorá môže transformovať každý krok výrobného procesu z dodávateľského reťazca a podniku na obchodných a koncových užívateľov. Cieľom je zvýšiť produktivitu a inovácie a posilniť podnikanie v integrovanom výrobnom prostredí riadenom údajmi.

V našom článku sa budeme venovať optimalizácii vybraného pracoviska vo výrobnom podniku prostredníctvom softvéru Tecnomatix Process Simulate od spoločnosti Siemens. Dané pracovisko nutne potrebovalo technologickú a softvérovú modernizáciu, odstránenie niektorých zbytočných úkonov a zníženie veľkého počtu operácií. V spomínanom softvéri sme si vytvorili súčasný stav pracoviska a postupne sme ho pretvárali na modernejší a úspornejší požadovaný stav. Nakoniec sa nám podarilo dosiahnuť stanovený cieľ, ktorého výsledky budú bližšie rozobraté v článku [3].

Porovnanie pôvodného stavu pracoviska s novonavrhnutým

Z hľadiska inovatívnych technológií je pôvodný stav pracoviska zastaraný. Mnoho úloh sa tu vykonáva ručne, takže je nutná reorganizácia a optimalizácia [4]. Pracovisko na výrobu elektromotora pozostáva z 27 prevádzok, ktoré sú označené veľkými písmenami PI a zodpovedajúcim číslom prevádzky. Takto označený proces výroby je od prvotnej kontroly, cez lisovanie, testovanie, vytvrdzovanie, lepenie, montáž až po konečnú kontrolu. Obrázok 1 zobrazuje pôvodné usporiadanie pracoviska.



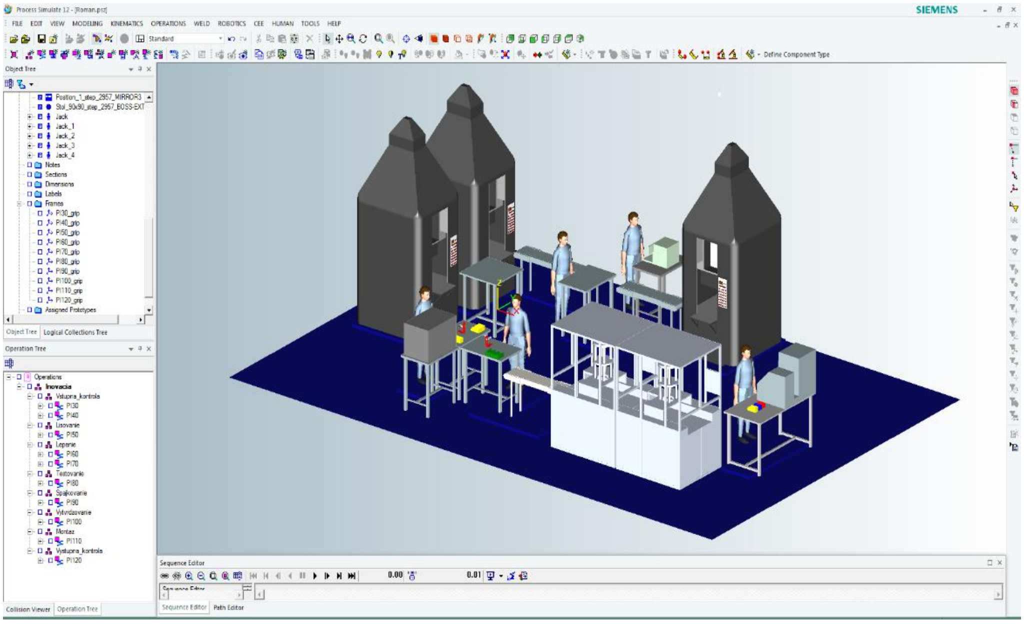
Obr. 1 Pôvodné usporiadanie pracoviska

V tabuľke 1 vidíme príslušné časy, počas ktorých sa vykonávajú operácie na pracoviskách a celkový čas výroby motora. Operácie, ktoré potom zoskupíme, sú farebne zafarbené.

Tab. 6 Trvanie jednotlivých operácií

Prevádzkové označenie	**Čas (min.)**	**PI - 100**	0,0333	**PI - 320**	0,0333
PI - 20	0,7725	**PI - 110**	0,2525	**PI - 330**	0,283
PI – 20_2	0,236	**PI - 120**	0,1801	**PI - 335**	0,0457
PI - 30	0.2390	**PI - 130**	0,0717	**PI - 340**	0,0765
PI - 40	0,268	**PI - 220**	0,1301	**PI - 350**	0,0693
PI - 50	0,1967	**PI - 230**	0,146	**PI - 360**	0,4438
PI - 60	0,1336	**PI - 240**	0,144	**PI - 380**	0,192
PI - 70	0,2813	**PI - 250**	0,2661	**PI - 390**	0,0929
PI - 80	0,1196	**PI - 300**	0,01	**Celkový čas výroby motora**	5,3158
PI - 90	0,3042	**PI - 310**	0,0396		

Po zlúčení prevádzok, ktoré boli v tabuľke označené žltou, modrou a fialovou farbou, sme vytvorili ucelenejšie a transparentnejšie usporiadanie a plynulejší tok materiálu počas výroby. Farebne označené operácie sme nahradili tromi vysoko presnými robotickými strojmi, ktoré vykonávajú úlohu oveľa rýchlejšie a efektívnejšie (Obr. 2). Úlohou človeka bolo umiestniť materiál na určité definované miesta v týchto strojoch a potom odniesť hotové výrobky [5], [6].



Obr. 2 Optimalizované pracovisko

V tabuľke 2 môžeme vidieť výrobné časy na jednotlivých pracoviskách po zmene. Vidíme, že počet operácií klesol z 27 na 11, čo je viac ako polovica. Nahradenie manuálnej práce robotmi nám umožnilo znížiť čas výroby jedného elektromotora z 5,38 minúty na 2,24 minúty, čo má pre túto spoločnosť veľký význam.

Tab. 7 Trvanie operácií po zmene

Prevádzkové označenie	Čas (min.)	PI – 90	0,3948
PI – 30	0,239	PI – 100	0,0259
PI – 40	0,2812	Stroj 1	0,2666
PI – 50	0,2589	Stroj 2	0,2666
PI – 60	0,1777	Stroj 3	0,2666
PI – 70	0,2893	Celkový čas výroby motora	**2,2415**
PI – 80	0,2951		

Záver

Dnes môžu roboty vykonávať rôzne úlohy a používajú sa takmer v každom priemysle. Interakcia človek - stroj sa čoskoro stane bežnou každodennou praxou. Na danom pracovisku sme sa preto rozhodli nahradiť manuálne náročné operácie robotmi [7], [8]. Výsledkom je plynulejší tok materiálu, zjednodušenie výrobného procesu a po prvé skrátenie výroby elektromotora o viac ako 3 minúty. Po zavedení tejto inovácie môže spoločnosť vyrábať viac elektromotorov súčasne.

Poďakovanie
Tento článok bol vytvorený realizáciou grantových projektov **VEGA 1/0438/20** Interakcia digitálnych technológií za účelom podpory softvérovej a hardvérovej komunikácie pokročilej platformy systému výroby, **KEGA 001TUKE-4/2020** Modernizácia výučby priemyselného inžinierstva za účelom rozvoja zručností existujúceho vzdelávacieho programu v špecializovanom laboratóriu, **APVV-17-0258** Aplikácia prvkov digitálneho inžinierstva pri inovácii a optimalizácii produkčných tokov a **APVV-19-0418** Inteligentné riešenia pre zvýšenie inovačnej schopnosti podnikov v procese ich transformácie na inteligentné podniky.

Použitá literatúra

[1] EDL M., LERHER T., ROSI B. 2013. „Energy efficiency model for the mini-load automated storage and retrieval systems “. International Journal of Advanced Manufacturing Technology, č. 2013, s. 1-19. ISSN: 0268-3768.
[2] MARKULIK Š., CEHLÁR M., KOZEL R. - 2018. Process approach in the mining conditions, In: Acta Montanistica Slovaca. Roč. 23, č. 1 (2018), s. 46-52. - ISSN 1335-1788 Spôsob prístupu: https://actamont.tuke.sk/ams2018.html.
[3] TREBUŇA, P., POÓR, P., HALČINOVÁ, J. Example for Determining of Metrics (Degree of Dissimilarity) of Objects Cluster Analysis. In 2013 International Conference on Frontiers of Energy, Environmental.
[4] STRAKA M., KHOURI S., ROSOVA A., CAGANOVA D., CULKOVA K. 2018. Utilization of computer simulation for waste separation design as a logistics system, International Journal of Simulation Modelling, Vol. 17, No. 4, pp. 583-596.
[5] BUCKOVA, M.; KRAJCOVIC, M.; EDL, M (2017) Computer simulation and optimization of transport distances of order picking processes: 12TH INTERNATIONAL SCIENTIFIC CONFERENCE OF YOUNG SCIENTISTS ON SUSTAINABLE, MODERN AND SAFE TRANSPORT, Procedia Engineering, Volume: 192 Pages: 69-74, DOI: 10.1016/j.proeng.2017.06.012.
[6] KŁOS S. 2015. Implementation of the AHP method in ERP-based decision support systems for a new product development. Communications in Computer and Information Science. ISSN 1865-0929.
[7] FUSKO, M.; BUCKOVA, M.; GASO, M.; KRAJCOVIC, M.; DULINA, L. ; SKOKAN, R. (2019) Concept of Long-Term Sustainable Intralogistics in Plastic Recycling Factory: Sustainability, Volume: 11, Issue: 23, Article Number: 6750, DOI: 10.3390/su11236750.
[8] MANLIG, F.; SLAICHOVA, E.; KOBLASA, F.; VAVRUSKA, J.(2014) Innovation of business processes by means of computer-aided simulation: Novel Trends In Production Devices And Systems, Applied Mechanics and Materials, Volume: 474, Pages: 67-72, DOI: 10.4028/www.scientific.net/AMM.474.67.

Contact address

Ing. Jozef Trojan
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: jozef.trojan@tuke.sk

Review process

Single-blind peer review process.

THE IMPACT OF DIGITIZATION ON THE DEVELOPMENT OF HUMAN POTENTIAL

Miriam PEKARČÍKOVÁ – Peter TREBUŇA – Štefan KRÁL – Michal DIC

Abstract: Existuje mnoho ľudí, ktorí tvrdia, že ľudský faktor už nebude v budúcnosti vo výrobe potrebný. Nie je to len nesprávne, ale z ekonomických dôvodov to nemá zmysel. Inteligentná výroba znamená nielen vysoký stupeň automatizácie, ale taktiež zvýšenú potrebu pracovníkov, ktorí disponujú expertnými vedomosťami v špecifických odvetviach, taktiež interdisciplinárnymi schopnosťami a zručnosťami ovládať nové technológie a softvéry v súčinnosti s tzv. mäkkými zručnosťami, ktoré nie je možné automatizovať ako plánovanie, koordinácia, vedenie, kooperácia. Článok sa orientuje do problematiky budúcnosti pracovnej sily v kontexte digitalizácie.
Abstract: Many people claim that the human factor will no longer be needed in production in the future. Not only is this incorrect, but for economic reasons it does not make sense. Intelligent production means not only a high degree of automation, but also an increased need for workers who have expert knowledge in specific industries, as well as interdisciplinary skills and abilities to control new technologies and software in conjunction with the so-called soft skills that cannot be automated such as planning, coordination, leadership, cooperation. The article focuses on the future of the workforce in the context of digitization.
Keywords: digitalization, work, automatization, technology
Kľúčové slová: digitalizácia, práca, automatizácia, technológia

Úvod

Technologický pokrok rapídne posúva hranice medzi pracovnými úlohami, ktoré realizujú ľudia a ktoré sú zabezpečované prostredníctvom strojov a algoritmov. Pokiaľ bude táto transformácia vedená rozumne, povedie nielen k zvýšeniu produktivity, ale taktiež k zvyšovaniu kvality životnej úrovne. V opačnom prípade môže predstavovať riziko rozširovania rozdielov v kvalifikácii, nerovnosti a väčšej polarizácii. Výskumy *World Economic Forum* spracované v správe (pre časový rámec 2018-2022) „Future of Jobs Survey 2018“ naznačujú, že do roku 2022 je možné vplyvom zavádzania technológií do existujúcich pracovných miest očakávať uvoľnenie pracovníkov a ich presun na pracovné miesta, ktoré budú zamerané na uvažovanie a rozhodovanie.

Rozdiely medzi prácou dnes a v budúcnosti, ktoré súvisia so zavádzaním nových technológií a digitalizáciou sú zobrazená na obr.1. Jedná sa o zmenu charakteru činností, ktoré budú zabezpečované pracovníkom, a ktoré budú automatizované. Pracovník už nebude priamo zabezpečovať tvorbu pridanej hodnoty, ale náplň jeho práce bude zameraná na monitorovanie procesov a robotov, údržbu zariadení, vyhodnocovanie dát a spracovanie analýz, a pod. Cieľom transformácie by malo byť využitie nových technológií pre dosiahnutie vyššej úrovne efektívnosti výroby a spotreby, expandovanie na nové trhy s výrobkami, ktoré reflektujú potreby globálnej spotrebiteľskej základne.

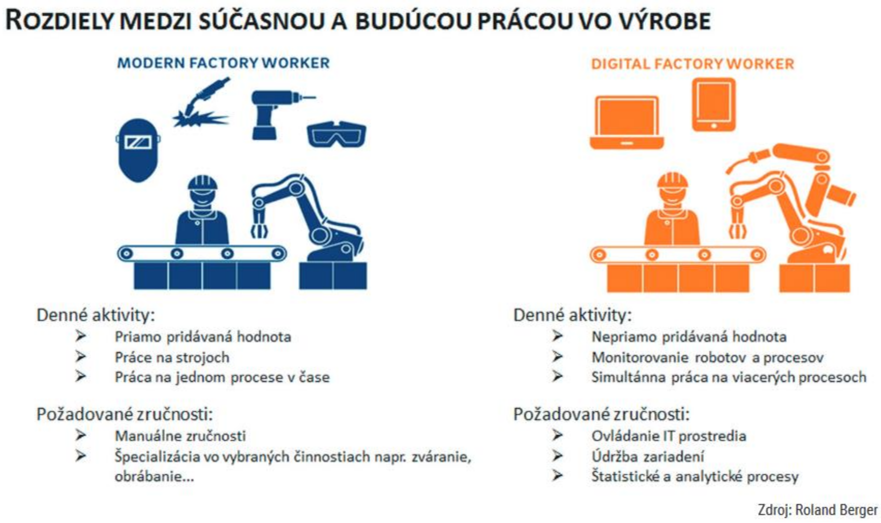


Fig. 1 Rozdiely medzi prácou dnes a v budúcnosti vplyvom Industry 4.0 [19]

Podľa zdroja [18] budú vplyvom Industry 4.0 vznikať nové hybridné odvetvia, ako digitálna medicína, presné poľnohospodárstvo a inteligentná výroba. Tie podporia vznik nových pracovných miest, ktoré môžu mať podobný charakter, ale budú si vyžadovať vynikajúce analytické schopnosti a zručnosti pri používaní digitálnych technológií. Stroje preberú manuálnu a rutinnú prácu a ľudia sa budú realizovať cez svoje jedinečné schopnosti a zručnosti, ako sú tvorivé riešenie problémov, komplexné formy komunikácie, schopnosť prispôsobiť sa neznámym situáciám.

Spolupráca človek vs. robot predstavuje iný spôsob zvyšovania produktivity, keďže je výsledkom kombinácie flexibility človeka a presnosti a konzistencie stroja (príkladom je napr. spoločnosť Amazon, ktorá v dôsledku kooperácie človek - robot plní objednávky až o 70% rýchlejšie – roboti zabezpečujú vychystávanie, ľudia zlepšujú procesy zaskladňovania, vychystávania a kompletizácie objednávok). Internet využívaný v priemysle zvyšuje pružnosť systému ako celku. Pripojením sa do siete odkiaľkoľvek je pracovník schopný asynchrónne a diaľkovo pracovať na riešení problémov týkajúcich sa strojov, nastavení strojov samostatne, resp. v koordinácii s on-line pripojenými spolupracovníkmi.

Vplyv digitalizácie na rozvoj ľudského faktora

Ľudský faktor v kontexte Industry 4.0 bude stále jedným z najdôležitejších faktorov. Bude súčasťou inteligentnej továrne prostredníctvom kreatívnych a asociatívnych kompetencii. Jedná sa o prirodzené schopnosti človeka jeho inteligenciu, kreativitu, motoriku a empatiu zodpovedne a rozumne nasadiť pri riešení rôznych situácii. Toto bude rozhodujúce pre úspech Industry 4.0. Úlohy a aktivity, ktoré by mal ľudský faktor v zmysle Industry 4.0 zastávať je podľa [18] možné kategorizovať nasledovne:

1. Ľudské zmyslové (senzorické) schopnosti: aj v budúcnosti budú vo výrobných procesoch vznikať zložité a nejednoznačné situácie, ktoré bude potrebné riešiť nasadením ľudského faktora.
2. Ľudská schopnosť rozhodovať sa, a s tým spojený spôsob myslenia: riešiť konflikty medzi zosieťovanými strojmi a zariadeniami, rozhodovanie v kritických situáciách.
3. Ľudská reakcieschopnosť a schopnosť vyjednávať: zložitosť systému, nepravidelné opakovanie, flexibilita, využitie moderných technológii, reakcie v reálnom čase.

Monotónne činnosti sa zautomatizujú a zrobotizujú, čím sa dosiahne vyššia produktivita, efektívnosť a kvalita produkcie, zlepší sa využiteľnosť pracovného času, keďže straty času už nebudú tvoriť prestoje súvisiace s prestavením a nastavením stroja, resp. s jeho údržbou. So zvyšovaním produktivity, dochádza aj k zvyšovaniu miezd a zvyšovaniu životnej úrovne. V zdroji [18] je uvedené, že v súčasnosti je v priemysle zavedených 2 milióny robotov, v SR je to predovšetkým vo finalizačných továrňach automobiliek. Samotné pridávanie robotov (nejedná sa o výmenu ľudí za robotov) vytvára celosvetovo až 0,4% HDP ročne. Robotizácia teda neznamená zvyšovanie nezamestnanosti, ale zmenu charakteru náplne práce, zvýšené nároky na kvalifikáciu, nadobudnutie nových znalostí a kompetencii so zameraním na sofistikované aktivity.

Podľa prof. Mindella (priekopník autonómnej robotiky) najvyššou formou technológie nie je úplná samostatnosť, ale automatizácia a autonómnosť stroja „elegantne“ prepojená s ľudským operátorom.

Človek bude zastávať významné postavenie v súvislosti s jeho odbornými znalosťami a zručnosťami v oblasti výrobných a zákazníckych potrieb s potenciálom vývoja technológii, ktoré budú odpovedať na nové budúce trendy. Hlavným cieľom Industry 4.0 je využiť silné stránky ľudí a robotov a smerovať k čo najvyššej miere efektívnosti a produktivity výroby, obr. 2.

Fig. 2 Ľudský faktor v Industry 4.0 [18]

Hlavným hnacím motorom organizácie práce v budúcnosti bude schopnosť kreatívne a inovatívne myslieť a zrealizovať návrhy prostredníctvom existujúcich technológii. Hlavnou úlohou manažmentu podniku bude predovšetkým motivácia svojich zamestnancov. Roboti budú naďalej dostávať inštrukcie od človeka. [18] Výrazne stúpne význam tzv. *emočnej inteligencie*, ktorá je predpokladom práce v tímoch. Vzájomná interakcia a motivácia budú hlavným motorom rozvoja podnikov. Potrebná je zmena hierarchie hodnôt človeka a podniku, ktoré by mali byť postavené na pocite istoty.

Industry 4.0 je potrebné chápať ako koncept, ktorého cieľom je zvyšovanie konkurencieschopnosti cez kolaboráciu a zosieťovanie, podporu kreativity a inovatívnosti, efektívneho využívania zdrojov, odstránenie monotónnej a fyzicky namáhavej práce, vytvárania čistejšieho a bezpečnejšieho pracovného prostredia, zosúladenie pracovného a rodinného života.

Správa „Future of Jobs“ (2016, Svetové ekonomické fórum) poukazuje na potrebu zavádzania modelu celoživotného vzdelávania, ako jednu z možností prípravy odborníkov v požadovanom odbore. S tým však súvisí potreba tvorby novej infraštruktúry vzdelávania, ktorá zabezpečí kontinuálnu zmenu profesnej a vzdelanostnej úrovne. V tejto súvislosti vyvstávajú dva problémy, a to mentálna spôsobilosť populácie k trvalým procesom v tvorivej práci a problém adaptácie populácie na transformáciu komplexných systémov. V dôsledku geografických

nerovnomerností a polarizácie globálneho trhu práce a v súčinnosti s narastajúcou silou informačno-komunikačných technológií vzrastie význam práce na diaľku (flexibilná práca). Snahou bude zabezpečiť kvalifikovanú pracovnú silu so zručnosťami, ktoré podniky potrebujú. Tradičné modely zamerané na trvalé pracovné pomery budú vytláčané „pracovníkmi na voľnej nohe“, ktorí budú schopní zaplniť tento deficit zručností. [15, 16, 17]
Inteligentná výroba znamená nielen vysoký stupeň automatizácie, ale taktiež zvýšenú potrebu pracovníkov, ktorí disponujú expertnými vedomosťami v špecifických odvetviach, taktiež interdisciplinárnymi schopnosťami a zručnosťami ovládať nové technológie a softvéry v súčinnosti s tzv. mäkkými zručnosťami, ktoré nie je možné automatizovať ako plánovanie, koordinácia, vedenie, kooperácia, apod. Zvýši sa dopyt po tradičných pracovných pozíciách v oblasti IT (vývoj softvéru, vývoj a výskum systémov pre zvýšenie elektronickej bezpečnosti, tvorba dizajnu informačno-komunikačných sietí, apod.). Nový trh práce bude vyžadovať nové zručnosti a schopnosti založené na podpore integrácie digitálnej a ľudskej pracovnej sily. Funkčnosť zariadení a využiteľnosť technológií je závislá od znalostí zamestnancov s takýmito zariadeniami a technológiami pracovať. Dôležité klásť dôraz na efektívnu prípravu a vzdelávanie v školách aj vo firmách.
Vzdelávanie sa bude musieť zdynamizovať a prispôsobiť sa neustálemu vývoju digitálnych technológii a zabezpečovať pravidelné aktualizovanie znalostí a zručností pracovnej sily v podobe tvorby platforiem pre proces neustáleho učenia sa. Školenia a tréningy sa stanú štandardom v procese neustáleho zlepšovania podnikových procesov s cieľom dosiahnuť konzistentné výsledky. Pokrok nielen v oblasti technológií znamená, že pracovník bude musieť disponovať znalosťami a kompetenciami v rôznych odboroch. Pre podnik sa stane pracovník investíciou a nie nákladom. Už teraz je potrebné reflektovať na tieto skutočnosti a ľudí nastaviť na proces celoživotného vzdelávania.

Záver

Dôsledkom vplyvu digitálnych technológii na výrobné a obchodné procesy budú zmeny, ktorým bude potrebné čeliť experimentovaním s novými modelmi a reformovaním systému vzdelávania a odbornej prípravy. Flexibilné vzdelávanie bude musieť kopírovať potreby trhu práce. Klasický spôsob vzdelávania formou výkladu sa bude musieť pretransformovať na interaktívny spôsob zameraný na podporu rozvíjania kreativity, analytických schopností a kritického myslenia.
„Podľa štúdie *McKinsey* (2017) by do roku 2030 mala automatizácia nahradiť celosvetovo 400 až 800 mil. pracovných miest a až v 60% povolaní musí byť viac ako 30% činností automatizovaných. Podľa analýz až 65% detí nastupujúcich dnes do základných škôl skončí v type povolaní, ktoré dnes ešte neexistujú.“ [14]
S cieľom využiť transformačný potenciál štvrtej priemyselnej revolúcie budú lídri podnikov vo všetkých odvetviach a regiónoch stále viac podnecovaní k vypracovaniu komplexnej stratégie pracovnej sily, ktorá bude pripravená reagovať na výzvy tejto novej éry urýchľujúcich sa zmien a inovácií.
Medzi kľúčové faktory, ktoré budú musieť zvážiť patrí [13]:

- zmapovanie rozsahu prebiehajúcich zmien v zamestnaní a dokumentovanie vznikajúcich a klesajúcich typov pracovných miest,
- zdôraznenie príležitostí na využívanie nových technológií na zefektívnenie ľudskej práce a zlepšenie kvality pracovných miest,
- sledovanie vývoja zručností požadovaných v súvislosti so s prácou,
- zdokumentovanie potrieb investícií do rekvalifikácie, zvyšovania kvalifikácie a transformácie pracovnej sily.

Poďakovanie
Príspevok bol pripravený v rámci riešenia grantového projektu VEGA 1/0438/20 Interakcia digitálnych technológií za účelom podpory softvérovej a hardvérovej komunikácie pokročilej platformy systému výroby, KEGA 001TUKE-4/2020 Modernizácia výučby priemyselného inžinierstva za účelom rozvoja zručností existujúceho vzdelávacieho programu v špecializovanom laboratóriu, APVV-17-0258 Aplikácia prvkov digitálneho inžinierstva pri inovácii a optimalizácii produkčných tokov a APVV-19-0418 Inteligentné riešenia pre zvýšenie inovačnej schopnosti podnikov v procese ich transformácie na inteligentné podniky

References

[1] GREGOR, M., HODON, R., BIŇASOVÁ, V., DULINA, Ľ., GAŠO, M.: Design of Simulation-Emulation Logistics System. In: MM Science Journal, pp. 2498-2502, (2018).
[2] STRAKA, M., LENORT, R., KHOURI, S., FELIKS, J.: „Design of large-scale logistics systems using computer simulation hierarchic structure“, International Journal of Simulation Modelling, Vol. 17, No. 1, pp. 105-118, (2018).
[3] HEIZER, J., RENDER, B., MUNSON, Ch.: Operations Management: Sustainability and Supply Chain Management, Pearson, USA, ISBN 10: 0-13-413042-1 (2017).
[4] FUSKO, M., BUCKOVA, M., GASO, M., KRAJCOVIC, M., DULINA, L.;, SKOKAN, R.: Concept of Long-Term Sustainable Intralogistics in Plastic Recycling Factory: Sustainability, Vol.: 11, Issue: 23, Art. No.: 6750, doi: 10.3390/su11236750, (2019).
[5] LACIAK, M., SOFRANKO, M.: Designing of the technological line in the SCADA system PROMOTIC, Proceedings of the 2013 14th International Carpathian Control Conference, Rytro, Poland. (2013).
[6] ZATROCHOVÁ, M., KUPEROVÁ, M., JANÁKOVÁ, H.: Innovative education of graduates of technical schools as a factor for competitiveness. In ICERI 2018: Proceedings. 11th International Conference of Education, Research and Innovation, Seville, Spain, 12-14 November 2018. 1. vydanie. Valencia : IATED Academy, 2018, S.10198-10204. ISSN: 2340-1095. ISBN: 978-84-09-05948-5. V databáze DOI: 10.21125/iceri.2018.0914.(2018).
[7] HOFMANN, E., RÜSCH, M.: Industry 4.0 and the current status as well as future prospects on logistics, Computers in Industry, Vol. 89, (2017).
[8] FURMANN, R., FURMANNOVÁ, B.: Logistics and digital twin, InvEnt 2017: Industrial Engineering –Invention for Enterprise, Wydawnictwo Fundacji Centrum Nowych Technologii, ISBN 978-83-947909-0-5, Szczyrk, PL, (2017).
[9] HOLMAN, D., WICHER, P., LENORT, R., DOLEJŠOVÁ, V., STAŠ. D., GIURGIU, I.: Sustainable logistics management in the 21st centruy requires wholeness systems thinking, *Sustainability*, 10 (12), ISSN 2071-1050 (2017).
[10] M. STRAKA, J. SADEROVA, P. BINDZAR, T. MALKUS, AND M. LIS, “Computer simulation as a means of efficiency of transport processes of raw materials in relation to a cargo rail terminal: A case study,” ACTA Montan. SLOVACA, vol. 24, no. 4, pp. 307–317, 2019.
[11] BOUSONVILLE, T.: Logistik 4.0: Die digitale Transformation der Wertschöpfungskette, Springer Gabler, Wiesbaden, ISBN 978-3-658-13012-1 (2017).
[12] DULINA, L., RAKYTA, M., SULIROVA, I., ŠELIGOVA, M.: Improvement of the Production System. In: Smart City 360°. 2nd EAI international Summit: revised selected papers. Ghent: EAI, (2017).
[13] http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf[26]

[14] http://ceitgroup.eu/index.php/sk/digital-factory-sk
[15] http://www.ekonom.sav.sk/uploads/journals/336_wp_86_stanek_pauhofova_2016.pdf
[16] https://openiazoch.zoznam.sk/cl/175300/Svet-bez-prace-je-iluzia-vzdy-budu-existovat-problemy-ktore-nezvladnu-stroje
[17] http://reports.weforum.org/industrial-internet-of-things/4-shift-towards-an-integrated-digital-and-human-workforce/4-2-creating-new-jobs-in-hybrid-industries/9
[18] http://arbeitsmarkt.vdma.org/arbeit-4.0
[19] https://industry4um.sk/pre-nastupujucu-transformaciu-su-kvalifikovani-zamestnanci-klucovi

Contact address

doc. Ing. Miriam Pekarčíková, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: miriam.pekarcikova@tuke.sk

prof. Ing. Peter Trebuňa, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: peter.trebuna@tuke.sk

Ing. Štefan Král, PhD.
Slovak Legal Metrology n.o.,
e-mail: kral@slm.sk

Ing. Michal Dic
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: Michal.dic@gmail.com

Review process

Single-blind peer review process.

VYLEPŠENIE VÝROBNÝCH PARAMETROV V ZÁVODE NA SPRACOVANIE RÝB ZA POMOCI SIMULÁCIE

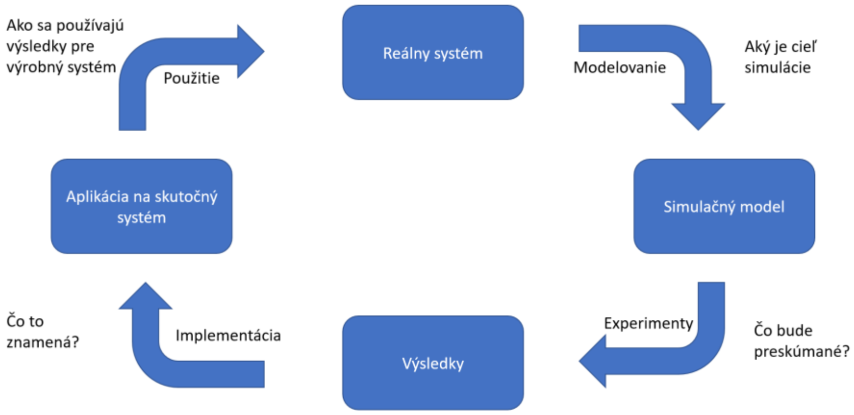
Marek KLIMENT – Peter TREBUŇA – Richard DUDA – Tomáš ŠVANTNER – Ján KOPEC

Abstrakt: Príspevok sa zaoberá činnosťou výrobnej spoločnosti na spracovania rýb a výrobu rôznych výrobkov z nich. Popisuje výrobný proces niektorých druhov výrobkov, jeho potreby a možné nedostatky. Cieľom projektu je eliminovať niektoré nedostatky v tomto výrobnom procese, prípadne ich inovovať a vylepšiť. Pre demonštráciu zlepšenia parametrov výrobného procesu sme využili prostriedok simulácie. Ako simulačný nástroj sme uplatnili softvér Tecnomatix Plant Simulation a niektoré jeho prostriedky.
Kľúčové slová: Simulácia, kvalita, výrobný proces, efektívita

Úvod

Simuláciu je možné definovať ako imitáciu reálneho procesu, alebo systému v priebehu času. Na to aby bolo možné simuláciu vytvoriť je potrebné najprv vytvoriť model. Model musí obsahovať hlavnú charakteristiku alebo funkciu daného fyzického alebo abstraktného procesu, alebo objektu. Simulácia predstavuje činnosť súboru procesov v čase, pričom model predstavuje samostatný systém. Je možné ju uplatniť za rôznych okolností, za účelom optimalizácie výrobného procesu ako celku, za účelom optimalizácie výkonu niektorej z častí systému, pre overenie celkovej efektívnosti tohto systému. Ďalej sa môže použiť na preukázanie prípadných skutočných účinkov alternatívnych podmienok a postupov. Simulácia sa používa aj vtedy, keď skutočný systém nie je možné zapojiť, pretože nemusí byť prístupný, alebo môže byť nebezpečné alebo neprijateľné zapojiť sa, alebo je navrhnutý, ale ešte nie je postavený.
Cieľom simulácie je dosiahnuť výsledky, ktoré možno preniesť do inštalácie v skutočnom svete. Navyše, simulácia definuje prípravu, vykonanie a vyhodnotenie starostlivo riadených experimentov v rámci a simulačný model. Spravidla spustíte simulačnú štúdiu pomocou nasledujúcich krokov, ktoré sú zobrazené na Obr. 1:

- Najprv sa pozrite na inštaláciu v skutočnom svete, ktorú chcete modelovať a zozbierajte údaje, ktoré ste potrebovali na vytvorenie simulačného modelu.
- Túto abstraktnú inštaláciu potom abstraktne vytvoríte a vytvoríte svoj simulačný model podľa cieľov simulačných štúdií
- Potom spustíte experimenty, t.j. vykonáte simulačné procesy s vaším simulačným modelom. To prinesie množstvo výsledkov, napríklad ako často stroje zlyhajú, ako často sú blokované
- Ďalším krokom bude interpretácia údajov, ktoré simulačné procesy produkujú.
- Nakoniec, vedenie manažmentu použije výsledky ako základ pre svoje rozhodnutia o optimalizácii



Obr. 3 Princípy similácie

Simulačné modelovanie bezpečne a efektívne poskytuje riešenie problémov v skutočnom svete. Poskytuje dôležitú metódu analýzy, ktorá je ľahko overiteľná, komunikovateľná a zrozumiteľná. Simulačné modelovanie v rôznych odvetviach a disciplínach poskytuje cenné riešenia tým, že poskytuje jasný prehľad o zložitých systémoch. Veľkými výhodami sú:

- Bezrizikové prostredie,
- Úspora času a peňazí,
- Vizualizácia,
- Náhľad do dynamiky,
- Zvýšená presnosť,
- Zvládnutie neistoty.

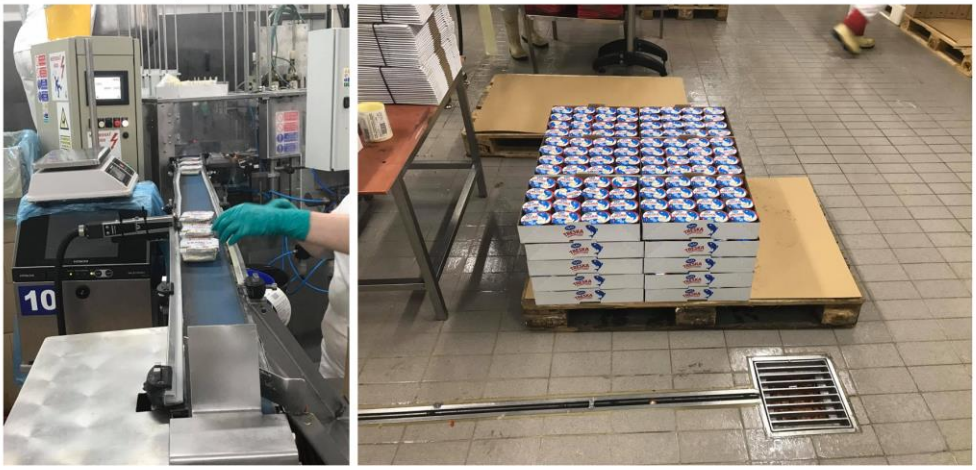
Výrobný proces v spoločnosti

Spoločnosť, ktorej problematikou sa zaoberá tento príspevok pôsobí na domácom ako aj medzinárodnom trhu niekoľko desaťročí a vo svojom sortimente ponúka veľké množstvo produktov rôzneho druhu. Ide o rôzne druhy šalátov, zavináčov, mrazených a údených rybacích výrobkov a podobne. Bolo by veľmi náročné v jednom simulačnom projekte zachytiť výrobu všetkých druhov výrobkov naraz, preto bolo zvolených niekoľko významných výrobkových reprezentantov a pri týchto boli riešiené dané výrobné problémy. Týmito výrobnými reprezentantmi budú Treska a Parížsky šalát. Tieto výrobky patria medzi najpredávanejšie produkty tohto výrobcu doma aj v zahraničí.

Priebeh výroby tresky

Výrobný proces Tresky sa začína prijatím zmrazených rýb zo skladu. Pred spracovaním sa mrazená rybacia surovina vybalí z transportných obalov a ukladá sa do rozmrazovacieho boxu, kde nastáva samotný proces rozmrazovania. Rozmrazovanie prebieha v popoludňajších a nočných hodinách. Doba rozmrazovania je 15 až 24 hodín. Po ukončení rozmrazovacieho procesu sa surovina vybalí z fólií a zároveň sa kontroluje kvalita rozmrazenej suroviny. Ďalším procesom je varenie vo varných komorách, ktoré trvá približne 90 minút. Po uvarení sa surovina schladzuje vzduchom v ochladzovacej komore približne 30 až 45 minút. Následne sa uvarená ryba dochladzuje vodou približne 30 až 45 minút. Vychladená uvarená rybacia surovina sa posúva na marinovanie, ktoré trvá 12 až 15 hodín. Po uplynutí doby marinovania sa lak vypustí a následne sa surovina poreže na mlynčeku. Takto spracovaný polotovar je pripravený na výrobu Tresky. Ďalším procesom je pripravenie sterilizovanej zeleniny, ktorá sa musí opláchnuť a následne po vysypaní do nádob so sitom nechá minimálne 5 minút odkvapkať. Ďalšie potrebné polotovary ako majonéza sú vopred pripravené a uložené na svojom mieste, odkiaľ sa presunie predpokladaný objem na daný deň na návažku. Ostatné prídavné látky sa navážia podľa materiálovej normy a pridávajú sa pri navážke zmesi na Tresku. Po navážení jednotlivých polotovarov a prídavných látok sa nádoba presunie do výrobnej miestnosti, kde prebieha predposledná fáza výroby. Navážená zmes sa vysype do stroja, v ktorom prebieha miešanie a vymiešaná zmes Tresky sa následne presúva do zásobníka. Zmes zo zásobníka sa postupne presúva do stroja a prichádza k samotnému plneniu Tresky do vopred označených téglikov. Stroj vyznačí správny dátum spotreby. Výrobky sa následne presúvajú po dopravníku ku procesu balenia. Na tomto dopravníku je umiestnený snímač, ktorý skenuje celý výrobok. Tento snímač kontroluje, či je na tégliku správne vytlačený dátum minimálnej spotreby (Obr. 2 a)).

a) b)



Obr. 4 Kontrola dátumu minimálnej spotreby b) Balenie výrobkov do kartónov

Pokiaľ na balení dátum nie je vytlačený, snímač tento výrobok automaticky vyradí pomocou výklopky do zásobníka pri dopravníku. Tieto výrobky následne obsluha vráti naspäť do označovacieho zariadenia pre uvedenie dátumu minimálnej spotreby. Pracovník zabalí požadovaný počet 16 kusov výrobkov do papierového kartónu a preloží na paletu (Obr. 2 b)). Pokiaľ ide o výrobky pre vyššie uvedeného zákazníka, ktorý požaduje navyše kontrolu na prítomnosť nežiadúcich telies, tak sa celá paleta s výrobkami presúva k samostatne stojacemu detektoru. Na tomto detektore sa postupne kontrolujú všetky výrobky zabalené v papierovom kartóne. Túto kontrolu vykonáva pracovník, ktorý postupne z palety berie kartóny s výrobkami a vkladá ich do detektora. Pokiaľ detektor zaznamená nežiaduce častice, celý kartón je automaticky vyradený. Kartóny, ktoré sú v poriadku pracovník uloží naspäť na paletu a táto postupuje ďalej na zabalenie palety fóliou na bezpečný prevoz výrobkov do expedičného skladu odkiaľ sa postupne rozvážajú podľa objednávok do pobočiek a k zákazníkom.

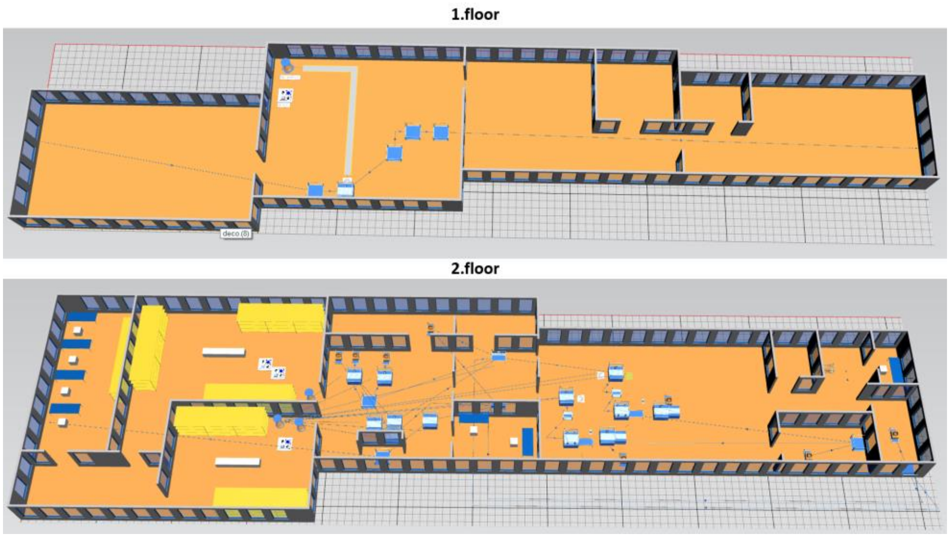
Priebeh výroby Parížskeho šalátu

Výrobný proces Parížskeho šalátu je veľmi podobný ako je tomu pri výrobe Tresky. Proces sa odlišuje na začiatku výrobného procesu, kde sa namiesto spracovania treskovitých rýb spracováva saláma. Saláma sa nakrája na automatickom krájači. Po nakrájaní sa saláma lakuje približne 2 hodiny. Po uplynutí času lakovania sa lak vypustí, vymarinovaná saláma sa nechá

odtiecť a následne sa používa pri výrobe šalátu. Ďalším procesom je pripravenie sterilizovanej zeleniny, ktorá sa musí opláchnuť a následne po vysypaní do nádob so sitom sa nechá minimálne 5 minút odkvapkať. Majonéza ako polotovar je vopred pripravená a uložená na svojom mieste, odkiaľ sa presunie predpokladaný objem na daný deň pomocou FIFO systému na návažku. Od tohto kroku je výrobný proces s treskou zhodný, líši sa len receptúrou, ktorá sa pri jednotlivých krokoch a navažovaní surovým riadi materiálovou normou daného výrobku.
Niektorí zákazníci predmetného výrobcu z hľadiska kvality požadujú okrem bežných kontrol, ktoré výrobca vykonáva vo vlastných laboratóriách a veterinárnych kontrol, ktoré sú vykonávané externe, navyše kontrolu na prítomnosť cudzích nebezpečných častíc ako sú kovy, sklo, plasty, drevo a podobne. Tieto kontroly pre týchto zákazníkov vykonáva výrobca vo svojej réžii na samostatnom detektore, ktorý má umiestnený vo výrobnom procese. Kontrola na tomto detektore prebieha tak, že zamestnanec všetky výrobky pobalené v kartónových obaloch privezie k tomuto detektoru. Výrobky berie po kartónoch z palety a vkladá ich do X-Ray detektora. Pokiaľ je balenie v poriadku, zamestnanec ho vráti naspäť na paletu, ktorú následne po zabezpečení na prevoz posunie do skladu hotových výrobkov. Takáto kontrola zaberá pomerne veľké množstvo času a vyžaduje si prítomnosť samostatného operátora, ktorý toto zariadenie obsluhuje. Spoločnosť má v pláne vyriešiť problém s kontrolou svojich výrobkov aplikovaním takéhoto snímača priamo na výrobnú linku, na ktorej by prebiehala takáto kontrola na všetkých výrobkoch a tým by mohla deklarovať nezávadnosť a zvýšenie kvality všetkých výrobkov. Spoločnosť ďalej plánuje zautomatizovať proces balenia nasadením manipulačného robota k linke. Tento robot by zabezpečil balenie výrobkov do kartónových krabíc a tým by uľahčil prácu operátorovi, ktorý túto činnosť vykonáva manuálne počas celej pracovnej zmeny.

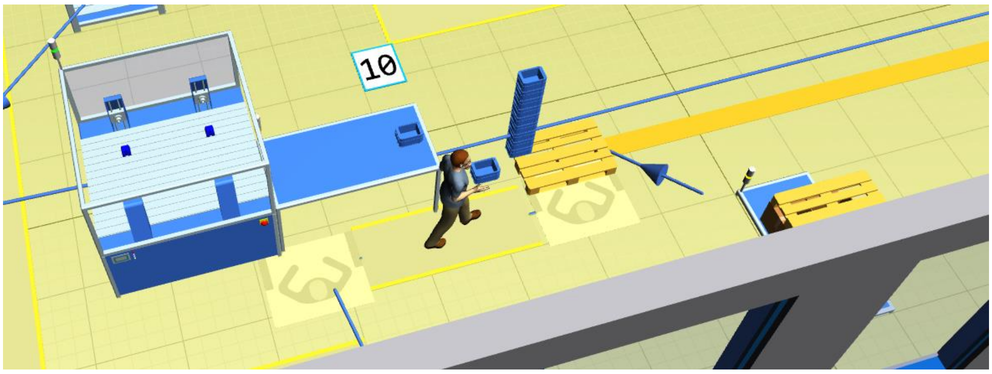
Simulácia výrobného procesu

Po zmapovaní a dôkladnej analýze celého výrobného procesu predmetných produktov bolo možné pristúpiť k spracovaniu simulačného modelu. Výrobný proces obidvoch produktov postupne prebieha na dvoch poschodiach výrobnej haly výrobcu.



Obr. 5 Digitálna podoba výrobného procesu v simulačnom module Tecnomatix Plant Simulation

Vo výrobných priestoroch na oboch poschodiach prebieha výroba ďalších výrobkov zo sortimentu spoločnosti. Simulačný model, sme však tvorili len na nami vybrané reprezentatívne výrobky. V tomto simulačnom modely nie je zahrnutá kontrola na X-ray detektore a balenie tu prebieha súčasným spôsobom. Pracovník ručne prenáša výrobky a ukladá ich do kartónov (Obr. 4).



Obr. 6 Súčasný stav na pracovisku balenia výrobkov

Na Obr. 5 môžeme vidieť štatistické zhodnotenie takéhoto výrobného procesu v normálnom a doterajšom stave. Zo softvéru sme prevzali štatistické údaje o základných ukazovateľoch, ako sú napríklad: Produktivita výrobného procesu, ktorá je pri tomto procese na úrovni 46,15%. ďalej môžeme sledovať to, koľko boli jednotlivé zariadenia v pracovnom režime, ako dlho boli blokované iným súvisiacimi operáciami, alebo ako dlho čakali na dokončenie operácii pred nimi.

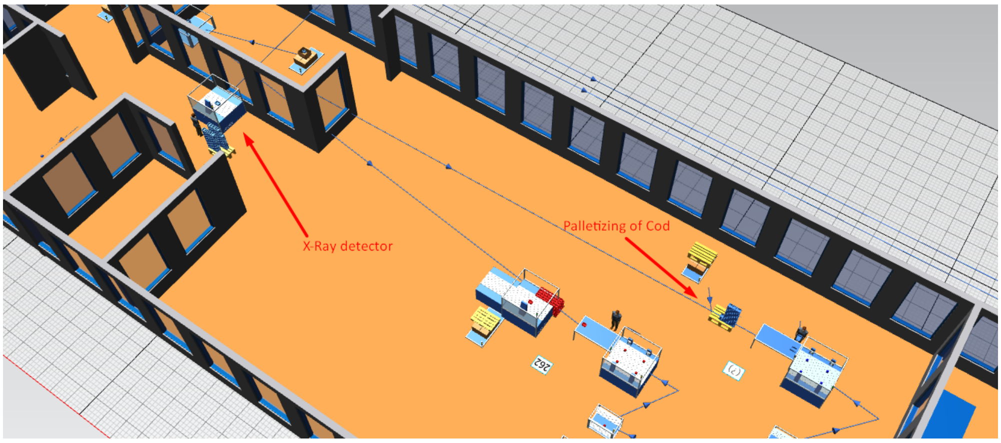
Cumulated Statistics of the Parts which the Drain Deleted									
Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
End_of_production	Pallete_of_cod	1:59:01.0441	7	1	46.15%	53.85%	0.00%	0.00%	

Object	Working	Set-up	Waiting	Blocked	Portion
Cod_decantation	51.00%	0.00%	0.00%	49.00%	
Weighing_of_cod	6.25%	0.00%	62.06%	31.69%	
Mixing_of_cod	15.63%	0.00%	9.01%	75.36%	
Cod_tray	0.15%	0.00%	5.93%	93.92%	
DS_2500	33.41%	0.00%	5.94%	60.65%	
Packaging_of_cod	50.00%	0.00%	50.00%	0.00%	
Palletizing_of_cod	55.53%	0.00%	44.47%	0.00%	

Obr. 7 Štatistické zhodnotenie súčasného stavu pri bežnej výrobe

Výrobný proces pri kontrole pomocou X-ray detektoru

Na ďalšom obrázku je znázornení do výroby zapojený aj spomínaný detektor na prítomnosť nežiadúcich telies vo výrobkoch, ako sú kovy, plasty, sklo a podobne.



Obr. 8 X- Ray detector vo výrobnom procese

Štatistické údaje zo softvéru pri takomto režime výroby sú znázornené na nasledujúcom obrázku (Obr. č. 7). Je názorne viditeľné, že výrobný proces v takomto režime je oveľa menej produktívny ako v predchádzajúcom prípade, kedy sa takáto kontrola nevykonávala. Z tohto dôvodu chce výrobca proces tejto kontroly vylepšiť a zvýšiť tým efektivitu a produktivity výroby všetkých produktov.

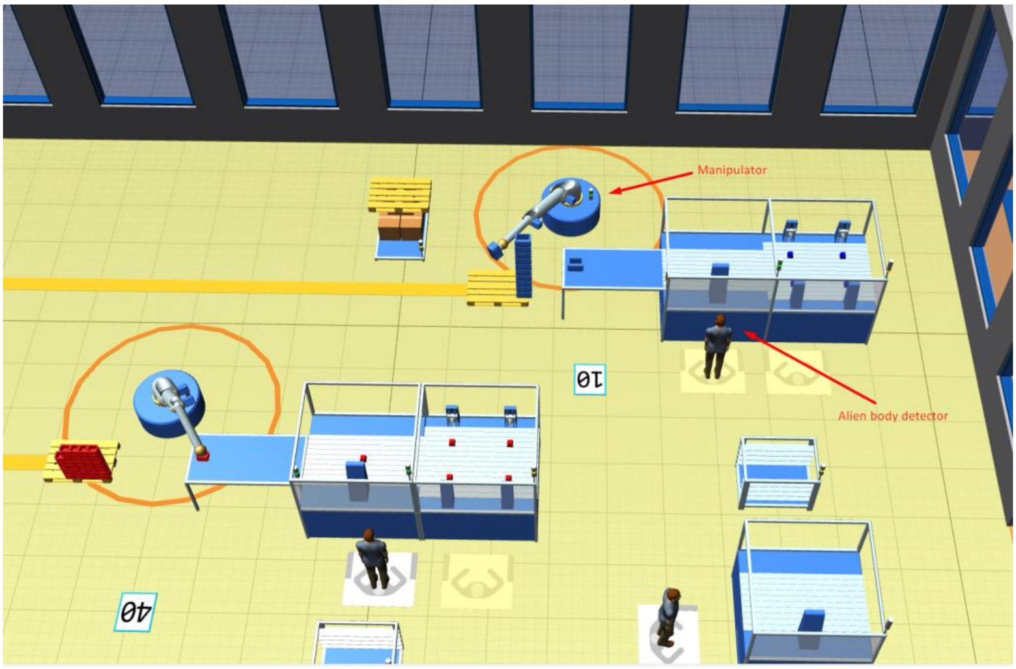
Cumulated Statistics of the Parts which the Drain Deleted									
Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
End_of_production	Pallete_of_cod	4:39:41.8999	5	1	19.03%	80.97%	0.00%	0.00%	

Object	Working	Set-up	Waiting	Blocked	Portion
Cod_decantation	51.00%	0.00%	0.00%	49.00%	
Grinding_of_cod	69.88%	0.00%	0.05%	30.06%	
Weighing_of_cod	6.25%	0.00%	62.06%	31.69%	
Mixing_of_cod	15.63%	0.00%	9.01%	75.36%	
Cod_tray	0.15%	0.00%	5.93%	93.92%	
DS_2500	33.41%	0.00%	5.94%	60.65%	
Packaging_of_cod	50.00%	0.00%	50.00%	0.00%	
Palletizing_of_cod	55.53%	0.00%	44.47%	0.00%	
X_ray_detector	51.28%	0.00%	18.60%	30.11%	

Obr. 9 Štatistické zhodnotenie pri činnosti X-Ray detector

Návrhy na zlepšenie výrobného procesu

Spoločnosť sa v prvom rade zaoberá riešením otázky eliminácie časovej straty pri potrebe použitia X-Ray detektoru pri objednávkach pre zákazníkov, ktorý túto kontrolu vyžadujú. Inovácia výrobného procesu by mala nastať aplikáciou detektoru priamo na výrobnú linku. Tento detektor by fungoval obdobným spôsobom ako v súčasnosti funguje snímač na dátum minimálnej spotreby produktu. Produkt sa presúva po dopravníkovom páse a pokiaľ snímač nezachytí vyznačený dátum spotreby výhybka na dopravníku tento výrobok vyradí mimo dopravník. Pri tomto mieste vo výrobe stojí operátor a takýto produkt vráti späť do výroby na miesto kde sa dátum vyznačuje. Takýmto spôsobom sa plánuje vyriešiť aj aplikácia detektoru na prítomnosť nežiadúcich častí vo výrobkoch. Produkt, v ktorom sa zaznamená nezhoda, bude vyradený automaticky mimo výrobu a následne celkov vyradený z výroby. Takýmto spôsobom dôjde jednak k skráteniu súčasného času tejto kontroly na externom detektore. Taktiež sa zníži počet vyradených výrobkov. V súčasnom stave kontroly sa kontrola uskutočňuje na výrobkoch, ktoré sú zabalené v kartónovom obale, podľa predpísaného počtu kusov téglikov s výrobkami na jedno balenie. Pokiaľ X-Ray detektor zaznamená nezhodu, mimo výrobu je vyradené celé balenie niekoľkých produktov. Po inovácii, by sa mali kontrolovať všetky tégliky s výrobkami samostatne a vyradený bude len konkrétny téglik, pri ktorom sa zachytí nezhoda. Aplikáciou tejto kontroly bude spoločnosť schopná deklarovať vykonávanie takejto kontroly u všetkých svojich výrobkov, nie len u výrobkov pre konkrétneho odberateľa, ktorý ju požaduje. Týmto sa zvýši kvalita všetkých výrobkov a vylepší sa spôsob deklarovania zdravotnej nezávadnosti produktov. Takýto spôsob kontroly priamo vo výrobnom procese by trval približne sekundu na každý produkt. Celkový výrobný takt by sa o tento čas predĺžil. Tento časový nárast by sa, ale eliminoval aplikáciou automatizovaného prvku do procesu balenia výrobkov do kartónov. Týmto krokom by sa odbúrala záťaž pracovníka, ktorý takéto balenie vykonával manuálne a každý výrobok jednotlivo ručne ukladal do kartónov na paletu. Tento pracovník by sa z pozície balenia mohol presunúť na pohodlnejšiu a menej namáhavú pozíciu ku Alien body detector a vykonávať odoberanie výrobkov, ktoré by tento detector označil ako chybné. Na obrázku 8 sú znázornené obidve návrhy zlepšenia výrobného procesu v simulačnom modely.



Obr. 10 Návrh implementácie inovačných riešení vo výrobnom procese

Na štatistickom vyhodnotení týchto návrhov je viditeľné zlepšenie súčasných parametrov výroby. Celková produktivita modelovanej výroby by vzrástla na 47,16%. Oproti pôvodnému stavu výroby, v ktorom sa nevykonávala ani kontrola nežiadúcich častí vo výrobkoch a manipuláciu vykonával manuálne pracovník došlo k nárastu o 1,1% celkovej produkcie.

Cumulated Statistics of the Parts which the Drain Deleted									
Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
End_of_production	Pallete_of_cod	1:25:53.6496	10	1	47.16%	52.84%	0.00%	0.00%	

Object	Working	Set-up	Waiting	Blocked	Portion
Cod_decantation	58.20%	0.00%	0.00%	41.79%	
Grinding_of_cod	80.96%	0.00%	0.05%	18.98%	
Weighing_of_cod	7.50%	0.00%	71.62%	20.88%	
Mixinf_of_cod	18.62%	0.00%	10.83%	70.56%	
Cod_tray	0.18%	0.00%	5.93%	93.89%	
DS_2500	26.30%	0.00%	47.29%	26.42%	
Alien_body_detector	40.09%	0.00%	33.52%	26.39%	
Packaging_of_cod	33.40%	0.00%	53.62%	12.98%	
manipulator	32.63%	0.00%	50.69%	16.68%	
Palletizing_of_cod	33.37%	0.00%	66.63%	0.00%	

Obr. 11 Štatistické zhodnotenie pri implementácii navrhovaných riešení

Záver

Zo simulácii a štatistických výsledkov z nich je zrejmé, že uplatnenie takéhoto nástroja v súčasnosti nachádza uplatnenie v rôznych oblastiach výroby. Je zrejmé, že aplikácia simulácie má význam nie len v oblasti automotive, ale aj v potravinárskom a inom priemysle. Simulačné nástroje dokážu napomáhať nie len pri projektovaní nových plánovaných výrob, ale aj pri vylepšovaní už existujúcich výrob. Napomáhajú v rozhodovacom procese, akú zmenu vo výrobnom procese uskutočniť bez nutnosti fyzického zásahu do tohto procesu. Po dôkladnom analyzovaní všetkých možností zlepšenia z rôznych hľadísk sa môžu vopred pripraviť moduly, ktoré sa do výroby nasadia, alebo nahradia, bez potreby prerušiť výroby na zdĺhavú prestavbu linky, ktorá by si vyžadovala dlhú odstávku výroby. Aj v tomto prípade je viditeľné zlepšenie v návrhu oproti pôvodnej situácii o 1,1%. Takýto nárast sa nemusí zdať veľmi závratný a na mieste je otázka, aká by bola návratnosť takejto investície pre spoločnosť. Do úvahy však treba brať fakt, že uvedenú simulačná štúda bola vykonaná len na malom počte výrobkových reprezentantov a v úvode je uvedené že výrobná spoločnosť má v portfóliu svojej ponuky niekoľko desiatok druhov výrobkov. Väčšina týchto produktov sa vyrába, alebo aspoň balí podobným spôsobom uvádzané produkty, ktoré boli zvolené ako príklad pre tvorbu takýchto modelov. Pokiaľ by sa u každého výrobku potvrdilo podobné navýšenie produktivity, doba návratnosti takýchto investícii by sa značne skrátila.

Poďakovanie

Príspevok vznikol za pomoci grantových projektov: VEGA 1/0438/20 Interakcia digitálnych technológií za účelom podpory softvérovej a hardvérovej komunikácie pokročilej platformy systému výroby, KEGA 001TUKE-4/2020 Modernizácia výučby priemyselného inžinierstva za účelom rozvoja zručností existujúceho vzdelávacieho programu v špecializovanom laboratóriu, APVV-17-0258 Aplikácia prvkov digitálneho inžinierstva pri inovácii a optimalizácii produkčných tokov, APVV-19-0418 Inteligentné riešenia pre zvýšenie inovačnej schopnosti podnikov v procese ich transformácie na inteligentné podniky.

Použitá literatúra

[1] GREGOR, M., HODON, R., BIŇASOVÁ, V., DULINA, Ľ., GAŠO, M.: Design of Simulation-Emulation Logistics System. In: MM Science Journal, pp. 2498-2502, (2018).

[2] EDL, M., LERHER, T., ROSI, B.: „Energy efficiency model for the mini-load automated storage and retrieval systems“. International Journal of Advanced Manufacturing Technology, č. 2013, s. 1-19. ISSN: 0268-3768, (2013)
[3] GREGOR, M.; HERCKO, J.; GRZNAR, P (2015) The Factory of the Future Production System Research: 2015 21st International Conference on Automation and Computing
[4] FUSKO, M.; BUCKOVA, M.; GASO, M.; KRAJCOVIC, M.; DULINA, L.; SKOKAN, R. (2019) Concept of Long-Term Sustainable Intralogistics in Plastic Recycling Factory: Sustainability, Vol.: 11, Issue: 23, Art. No.: 6750, doi: 10.3390/su11236750
[5] FEDORKO, G.; MOLNÁR, V.; HONUS, S.; NERADILOVÁ, H.; - KAMPF, R. (2018) The application of simulation model of a milk run to identify the occurrence of failures: International Journal of Simulation Modelling = IJSIMM. - Wolkersdorf im Weinviertel, DAAAM International Vienna Vol. 17, No. 3 (2018), s. 444-457 [print]. - ISSN 1726- 4529
[6] MANLIG, F.; SLAICHOVA, E.; KOBLASA, F.; VAVRUSKA, J.(2014) Innovation of business processes by means of computer-aided simulation: Novel Trends In Production Devices And Systems, Applied Mechanics and Materials, Volume: 474, Pages: 67-72, doi: 10.4028/www.scientific.net/AMM.474.67.
[7] KŁOS S. 2015. Implementation of the AHP method in ERP-based decision support systems for a new product development. Communications in Computer and Information Science. ISSN 1865-0929.
[8] CHROMJAKOVA, F., BOBAK, R., HRUSECKA, D.: Production process stability – core assumption of Industry 4.0 concept, 5 th International Conference on Manufacturing, Optimization, Industrial and Material Engineering, pp. 143-154, 2017.
[9] STRAKA M., LENORT R., KHOURI S., FELIKS J.: Design of large-scale logistics systems using computer simulation hierarchic structure, International Journal of Simulation Modelling, Vol. 17, No. 1, pp. 105-118,
[10] ROSOVA, A., MALINDZAKOVA, M.: Material flow - starting point for recovery of inputs in the production company, International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, 14th International Multidisciplinary Scientific Geoconference and EXPO, SGEM 2014; Albena; Bulgaria SGEM Vol. 3, no. 5, (2014).

Contact address
Ing. Marek Kliment, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: marek.kliment@tuke.sk

Review process
Single-blind peer review process.

METHODOLOGY OF CREATING A VIRTUAL ENVIRONMENT USING UNITY 3D GAME ENGINE

Marián Matys – Martin Krajčovič – Gabriela Gabajová – Beáta Furmannová – Natália Burganová

Abstract: Nowadays, it may be challenging to unify the process of creating a virtual environment for virtual reality (VR) utilization. This article presents a methodology, that proposes a uniform method of creating the virtual environment with emphasis on simplicity and straightforward workflow. Methodology describes every necessary step, from preparation, through scene building, to walking through scene using VR headset. As a verification, methodology was used as a tool for manufacturing system design in VR, to test its effectivity and capability. Creating a 3D virtual environment from a proposed 2D layout design, that allows walking through built scene using VR headset.
Keywords: Virtual environment, virtual reality, methodology, Unity 3D.

Introduction

Modern innovative solutions are continually proposed, and it is important to be able to implement these technologies the most optimal way [1]. Industry 4.0 influence creates the ideal environment for these implementations [2]. Virtual reality (VR) is slowly becoming a stable technology in many fields. Testing the proposed solutions in virtual world before its implementation can be crucial, especially with current trends focused on constant cost reduction [3]. Moreover, potential shortcomings and dangers can be captured in virtual simulations before a real-life implementation. Thanks to that, companies can focus on increasing the production speed and overall quality, while emphasize on physical health of its employees [4]. Virtual reality can also become a new prime teaching method. With educational centres implementing this technology, VR can even become a new mass medium [5]. Virtual reality training programs for employees are also steadily raising in popularity.

However, to correctly integrate the technology into selected solutions, one needs to know the principles of creating VR capable environment. To ensure the sufficient immersion of VR user, it is important to create a virtual environment corresponding with its real-life counterpart, containing all its elements [6-7]. This is no easy task, since correct replication of real environment requires simulation of its object, functions, and processes.

Presented methodology proposes a uniform method of creating a virtual environment using a game engine Unity 3D. Methodology contains methods and principles to ensure the smooth workflow and minimalization of errors, while focusing on creating an immersive virtual reality experience.

Methodology of creating a virtual environment

Main goal of the methodology is turning an existing or designed environment into the virtual one capable of VR immersion. It is relatively complex process consisting of several tasks that need to be done. After completion of every necessary step, the user can walk through the created virtual environment using VR headset and additional accessories. such as controller (joystick). However, before building the scene itself, some preparations are required. User must collect all necessary materials and references, such as layout, 3D models, dimensions etc. After that, the process of building the virtual environment using Unity 3D can begin.

To ensure that methodology is straightforward and easy to understand, entire workflow is visualized through the flowchart. This flowchart shows all the necessary task and requirements for the project’s completions step by step. Flowchart is presented at Fig 1.

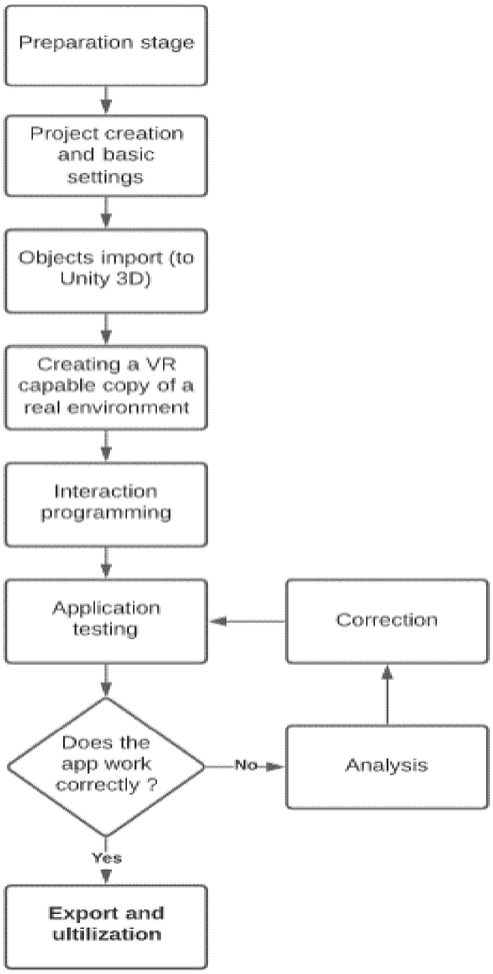


Fig. 13 Methodology flowchart [authors]

Preparation stage

Preparation stage takes place before the building the virtual scene in Unity 3D. Required task differ depending on the assignment, but the core remains the same. User needs to analyse presented scene and determine all means to create a realistic copy. Key part of building the scene is the 3D models library. User may have access to all necessary 3D models, but that will not always be possible. In that case, user must gather needed reference data (photos, dimensions) and create missing 3D models himself using 3D modelling software (Blender, Maya etc.).
When modelling, user must keep in mind that these objects will most likely be used to create a complex scene. This means that models should be adapted for this purpose. User should find a balance between how detailed these models are and how hard it will be to render them. Best solution is to stick to the basic principles. The most detailed objects are those that:

- Are important to simulate the basic functions of the scene.
- Are spacious, thus easy to notice and examine.
- Are ones that player will interact with.

If user has access to all models beforehand, it is good practice to check all of them before using them. Some of them may have to be simplified to reduce their performance impact. Simplification process can be done in 3D modelling software. Complexity of a object is determined by number vertices, the basic element of 3D model.

As an example, Fig. 2 shows the two versions of the cup model. One of them is very simple and the other one much more detailed. But both clearly indicate that object is, in fact, a cup. However, aside from case when this cup would be one the main object in the scene, the simplified version should be enough. Object like a cup will probably be put in the scene for aesthetic purposes rather than functional. Nevertheless, this version is likely too oversimplified. Nowadays, hardware is evolving at breakneck speed and even cheaper machines can handle a set of detailed objects. As mentioned before, it is all about finding a balanced depending on performance of user's hardware.

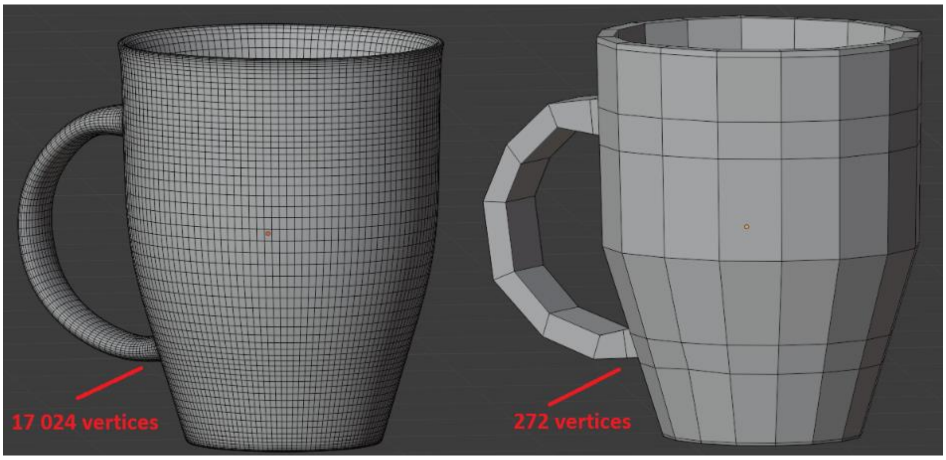


Fig. 14 Object complexity [authors]

Project creation and basic settings

After accumulating all necessary means for creation of selected virtual environment, user can begin to build his project in Unity 3D. Unity 3D is a game engine used for creation of various games and application. For this project, user will not use any complex Unity 3D function, so even a complete beginner can learn basics quickly, and then proceed to follow the methodology itself.

Firstly, user needs to decide on platform that scene will be built on. The two most valid option are PC (Windows) or a smartphone (Android, iOS). However, these two variants offer a different experience. Smartphone VR headset offers a cheap, but mobile VR experience, in exchange for low immersion and interaction options. On the other hand, desktop VR headset offers much vivid experience with rich spectrum of interaction, complimented by much higher price. Depending on chosen platform, user then may download a software development kit (SDK) that contains a lot useful tools. SDKs such as GoogleVR or SteamVR can be downloaded from the internet for free. Subsequently, it is time to create a new project in Unity 3D and set a basic parameters depending on preferred options. User must select platform he decided on, import SDK, if necessary, and finally fill in basic project settings (such as name, concrete VR hardware etc.) Fig. 3 shows the process of platform and project setup.

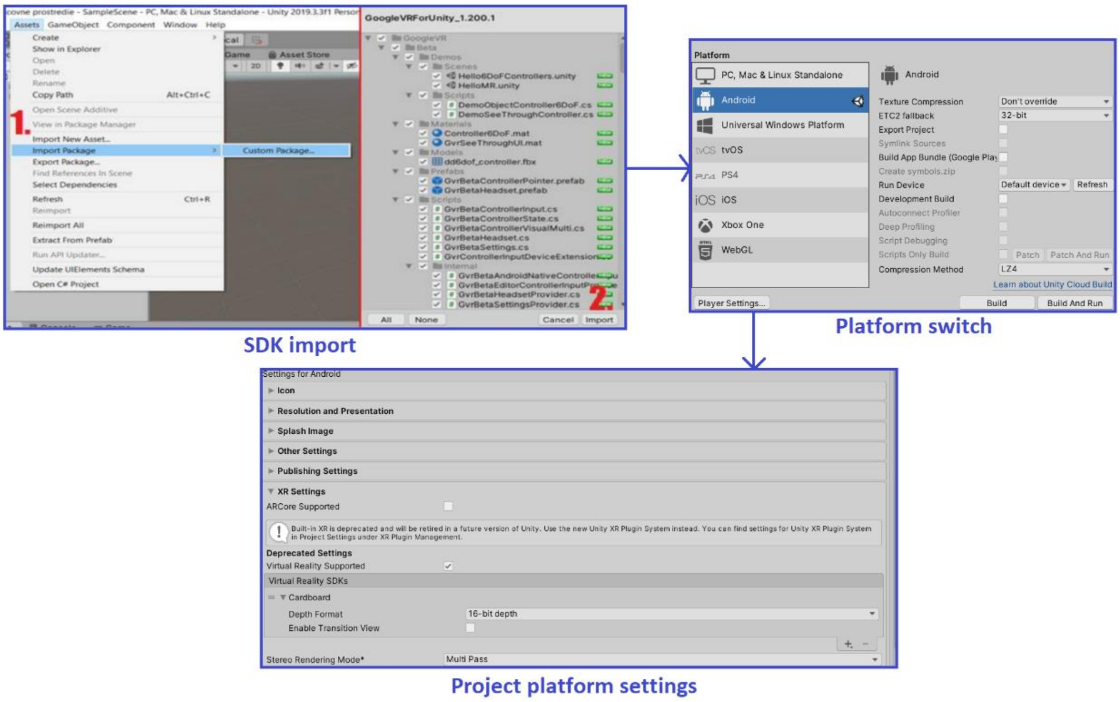


Fig. 15 Project setup [authors]

Objects import

The next step is an import of the model library into the Unity 3D. At this point every object should ready, that means all shortcomings were removed. Objects must be saved in correct format that Unity supports (such as .Fbx). Fig. 4 shows the import of object library to Unity 3D.

Fig. 16 Objects import [authors]

Creating a VR capable copy of the real environment

After importing all objects, the building of the scene itself is fairly straightforward. User simply drags and drops models to the scene and places them to match its real-life counterpart. A built-in coordinate system can be used to make that sure all object are within the correct distance from each other.

The approach for creating a scene depends on the user's preference. However, to prevent unnecessary mistakes and confusion, it is important to create a unified approach for a scene creation. Such approaches may be:

- Placing objects depending on their significance to the scene. For example, the most important objects will be placed first, followed by less significant ones.
- Gradual placing the objects from one side of the scene to the other. For example, placing the objects from left side to the right side. Objects all the way to the left will be placed first.
- Diving the scene into multiple areas. Each area can serve a different purpose or store different kinds of object. Scene then will be created by building area after area.

Fig. 5 shows an example of scene creation using the area by area method.

Fig. 17 Scene creation [authors]

Interaction programming

After the scene is completed, user needs to add means for player to interact with a virtual environment. This can be achieved by creating a script. Scripts are programs created with programming language C#. They allow user to create various scenarios to make a scene interactable and more vivid. The most basic script for virtual environment is addition of horizontal movement for a player. This may be enough if the goal of the scene is to showcase the created environment that represents a real or designed space. User needs to know the purpose of the VR scene he is creating and write required scripts accordingly. However, it is possible to find various scripts online, so even user with little programming experience can use and combine those, to achieve the state he needs.

Application testing

To test the current progress or the final product, user can build the application and run it with his head-mounted device (VR headset). He can launch the app on the pc, or export it to the smartphone, depending on the selected platform.
It is vital to find a fix any problems to ensure that the app is running smoothly. Inviting people to test it may bring extra data and new perspective for possible improvements. After perfecting the last details, the app is ready for its designed use. End user will export this app to his device. After launching it with his VR headset on, he must be able to walk through the scene using an assigned controller.

Methodology in practical use

To demonstrate the capability of the presented methodology, it was tested in a practical use. Concrete VR ready virtual environment was created using its principles. Firstly, a 2D layout of a bar material processing workplace was designed. The objective was to transform the assigned 2D layout into VR ready virtual workplace as a form of project visualization. This VR environment was then used for presentation of proposed workplace. Presentation participants could use the VR headset and controller to walk through the virtual 3D representation of designed 2D layout. A simple mobile VR headset was used, but for the presentation purpose, which minimize the user interaction options, it is a viable and significantly cheaper method. Thanks to that, participants got much closer look on every detail of proposed project, freely exploring every part. Fig. 6 shows the process of creating a virtual environment from assigned 2D layout. Fig. 7 shows the app itself.

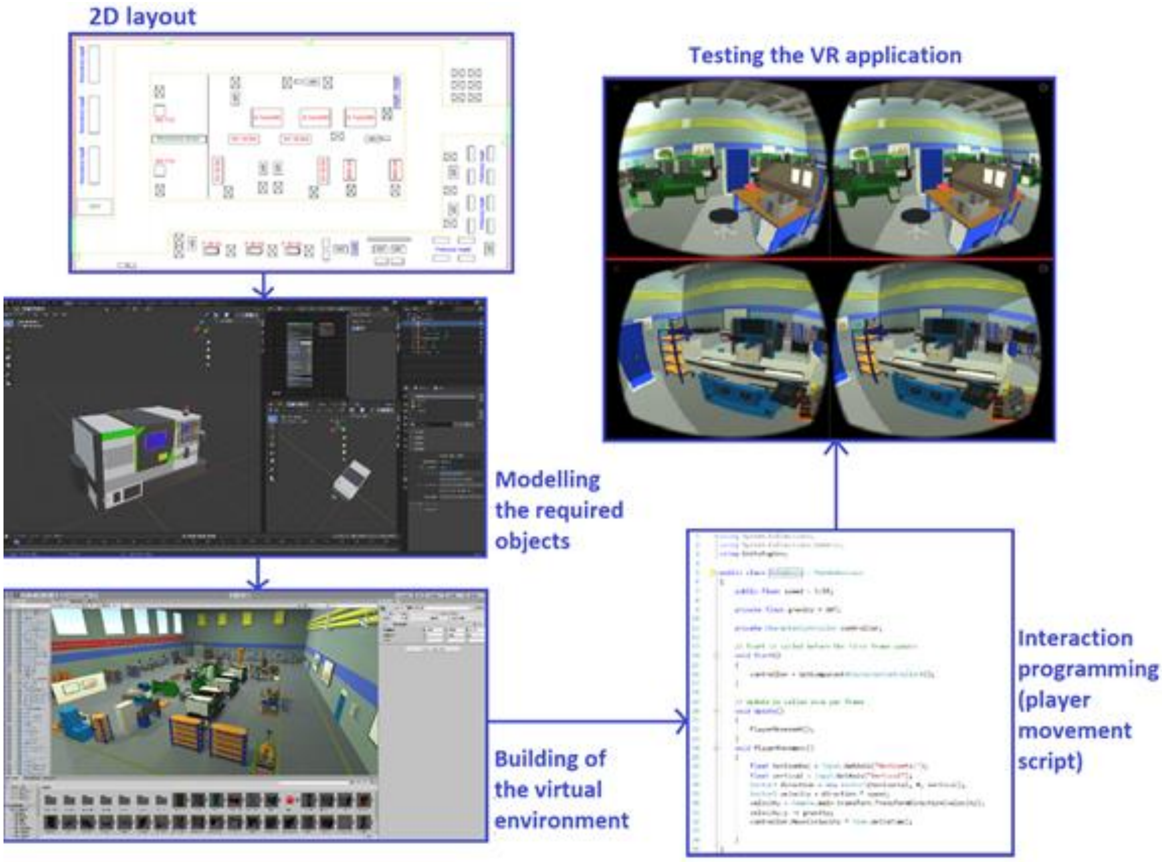


Fig. 18 Creating a virtual environment using presented methodology [authors]

Fig. 19 Proposed workplace in VR [authors]

Conclusion

Virtual reality is a technology that will most likely be part of many projects and processes in the near future. For this reason, article presents a methodology that will enable user to create a VR capable virtual environment. This methodology will lead the user through every necessary steps. From preparations, creating 3D models to testing the scene using VR headset. Methodology propose a several principles user should follow to ensure a simple and straightforward workflow.

To test the methodology in practical use, a concrete VR ready scene was created. Main goal was to turn an assigned 2D layout into VR capable 3D environment. User used presented methodology for every necessary steps. As the end result, user created a virtual environment capable of VR immersion suitable for its goal, which was the presentation of proposed workplace.

Methodology proved to be usable in the process of creating a virtual environment. Further experiment will be conducted to improve overall workflow to make it even more powerful tool in the field of virtual reality.

Acknowledgments: "This work was supported by the Slovak Research and Development Agency under the Contract no. APVV-19-0305”.

References

[1] FUSKO, M., et al.: Logistics and Technical service in Industry 4.0 concept. In: Daily automation. No. 6. May (2020), ISSN 2453-8175, pp. 1-10.
[2] PEKARČÍKOVÁ, M. – TREBUŇA, P. - KLIMENT, M. - ROSOCHA, L.: Material Flow Optimization through E-Kanban System Simulation. In: International Journal of Simulation Modelling. Vol. 19, No. 2 (2020), ISSN 1726-4529, p. 243-254.
[3] GRZNÁR, P., et al.: An optimization methodology for sustainable development of production lines. In: Zarządzanie Przedsiębiorstwem. Vol. 22, No. 4 (2019), pp. 2-6.

[4] HORVÁTHOVÁ, B., et al.: Data collection for ergonomic evaluation at logistics workplaces using sensor system. In: Transportation Research Procedia. Vol. 40 (2019), pp. 1067-1072.
[5] HOŘEJŠÍ, P., POLCAR, J., ROHLÍKOVÁ, L.: Digital Factory and Virtual Reality: Teaching Virtual Reality Principles with Game Engines. In: Virtual Learning. Rijeka: InTech, 2016, IBSN 978-953-51-2823-6, pp. 155-174.
[6] TREBUŇA, P. 2009.: Experimental modeling methods in Industrial Engineering. In: Acta Montanistica Slovaca. Vol. 14, No. 4 (2010), ISSN 1335-1788, pp. 335-340.
[7] TREBUŇA, P. - POPOVIČ, R. - PEKARČÍKOVÁ, M. - KLIMENT, M. - MARKOVIČ, J.: Virtual Commissioning in the digital factory. In: Průmyslové inženýrství. Plzeň: Západočeská univerzita, 2015, ISBN 978-80-261-0525-1, pp. 150-155.

Contact address

Ing. Marián Matys
University of Žilina, Faculty of Mechanical Engineering, Department of Industrial Engineering, Univerzitná 8215/1, 010 26 Žilina, Slovakia
e-mail: marian.matys@fstroj.uniza.sk

Review process

Single-blind peer review process.

VIRTUAL MANUFACTURING LINES

Štefan MOZOL – Patrik GRZNÁR – Milan GREGOR – Vladimir VAVRÍK – Marek SCHICKERLE

Abstract: Manufacturing and assembly lines are currently designed as a series of connected production facilities which used conveyor or other means of transport. The flow between these production facilities is regular. In the case of production facilities of fixed interconnected equipment products are processed in sequences. However, assembly lines that work with different product variations, as is the case in the automotive industry, are due to the impossibility of skipping a sequence have extended lead times. Virtual lines can be understood as production facilities which do not have fixed flows, and the final flow is decided by the bill of material (BOM) itself and the current state of production. Virtual lines, the compilation of which is determined by the BOM and the current situation, work on a negotiation mechanism where each production facility or production cell behaves as a service provider and the product as the customer who negotiates the best terms.
Keywords: virtual manufacturing line, dynamic control, competency islands

Introduction

Efficiency of manufacturing processes is often measured by the production lead time. Production lead times means time over which the production requirement is converted into the final product. In reducing it in production and assembly processes, the concept of optimisation can be encountered when current processes are examined from a product bill of material (BOM) perspective and on the basis of which action is decided [1,2]. However, this approach is not applicable everywhere. In the case of assembly processes in the automotive industry where there is a high degree of product portfolio variation, the problem arises of long production lead times and lower production and assembly capacity. An important role in the future will be played by the newly developed concept of competency islands, which is based on the division of usually continuous assembly lines into islands that provide services. The assembled car behaves with its platform as an autonomous element that follow its target (ie. installation of all components at the lowest possible production lead time and at the lowest cost). The competency islands which providing services negotiate with these agent products about their state and the services that must be provided. The route is thus no longer created fixed but is virtual selected on the basis of the current state and best conditions. Some rolling planning is taking place as part of this process, but the final decision on the route takes place only on the basis of a decision at the decision points. In this way, it is possible to reduce the production lead time at optimal cost and also obtain maximal equipment utilization. The article describes the dynamic planning of production as well as the description of the virtual production line creation (i.e. line which does not physically show any connection but the product chooses the route according to the current state so called virtual route).

Dynamic manufacturing control

Manufacturing planning is the arrangement of the company's future activities on the basis of anticipated (predicted) requirements for the type and quantity of products or known production orders when real production capacities are accepted [3]. This is especially useful when forecasts tend to be accurate and the order of fixed orders does not need to be adjusted. It is also based on a number of installations, their availability and the various other constants needed for capacity planning and scheduling [4,5]. However, the production environment is not constant and constantly changes (internal or external) and these are also reflected in production planning. Changing customer requirements and the application of personalised production normally takes production planning and management to the limit of efficient production possibilities. Current trends in production approaches are mainly in applications based on agents-based manufacturing. In such production, each entity in the production system gradually becomes an autonomous agent capable of autonomous action. Thanks to the application of agents, it is possible to plan production dynamically with over time evolving variables that represent individual system agents. In this way, it is possible to react much more flexibly to a change such as missing material, machine and equipment outages, contract prioritisation, etc. Reconfigurable manufacturing systems present potential in production opportunities precisely in systems whose capacities and functionality are constantly changing over time and a transition from classical manufacturing planning to dynamic is necessary [6]. For a competency island system that uses the principles of reconfigurability, it will be necessary, more than elsewhere, to use dynamic manufacturing planning and control because the route taken by the product may not always be the same as an identical product that was produced at a different point in time. The product creates a virtual manufacturing line at any moment according to the current status.

Virtual manufacturing lines and product as a central element of production

In the virtual manufacturing line in the Factories of the Future, the agent chooses where and how the operations are to be carried out so that the product is complete. The communication centre is an agent product. The agent product is created according to the production plan. Production facilities acting as agents share their current status and simulation of future status so that we have a complete environment for filtering appropriate data. Agent-based manufacturing, similar to cloud-based composite design and production, enables the application of a negation mechanism in which the agent filters the product and chooses its best route based on the current shared content of the production facilities. The direction of the optimal route is decided at the decision points see Fig 1.

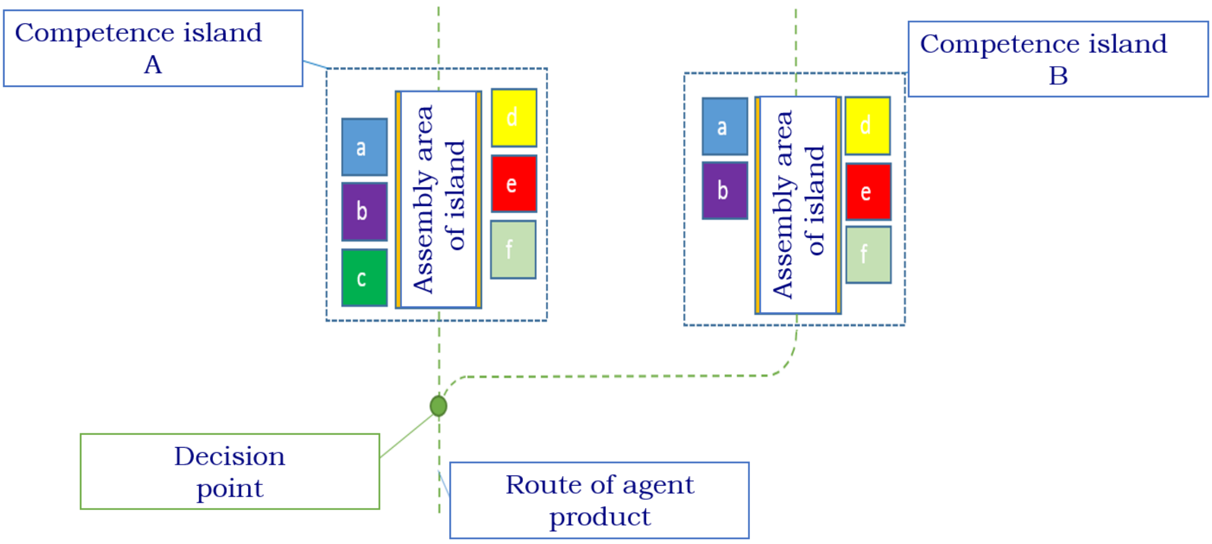


Fig. 1 Decision point as optimal route routing (Authors)

The direction of the optimal route is decided at the decision points. The manufactured product will behave like a smart entity in production, able to communicate with its surroundings and able to organize its processing completely autonomously. Such a product will determine its own sequence of processing, allocate the required capacity in the relevant competency islands and summon a mobile robot to transport it in production [7]. The decision point is the space where both calculation and negotiation take place after leaving the space in which the last operation was performed. The optimal route is therefore not determined at one point, but is gradually formed by means of the decision points see Fig. 2. There is therefore no decision on the route in advance, but there is an approximate plan in the context of the rolling planning. The route direction will therefore be decided by various parameters, such as:

- Services offered and their scope.
- Order queue for services entered by the product.
- Occupancy of the workplace
- Fault signalling.
- Predictive fault signalling.
- Current production costs.

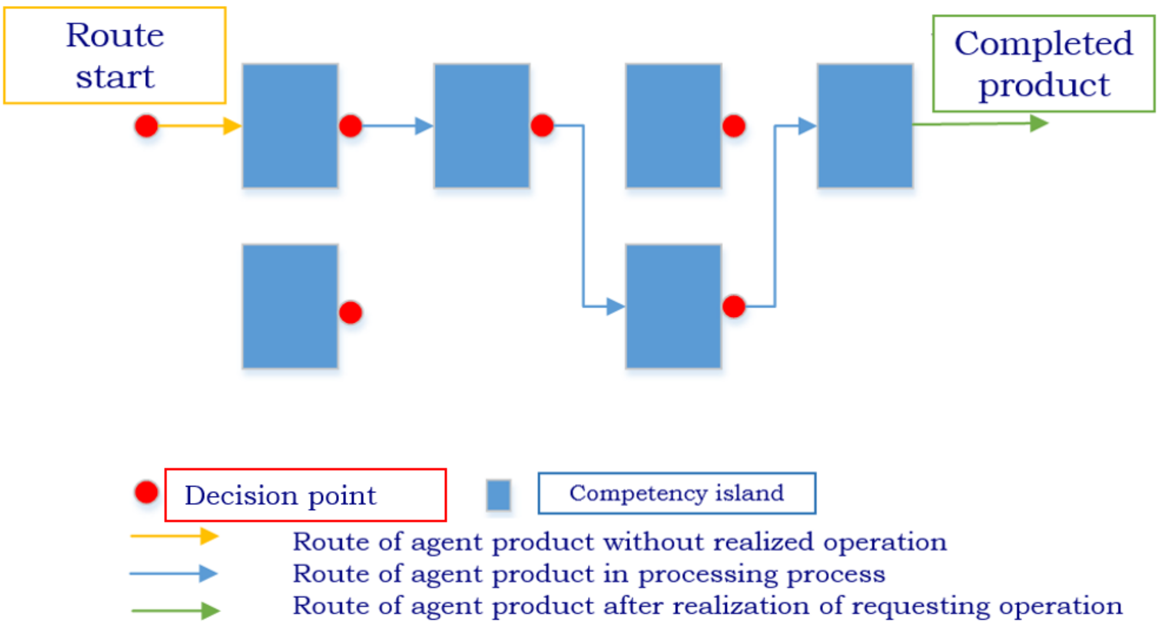


Fig. 2 Virtual manufacturing line (Authors)

Concept of competency islands

The competency Islands (CI), as a system, are based on a decentralised control in which each agent in the system knows its function. They are conceived as small, highly flexible production units which are deployed where there is sufficient real demand. Such production systems will be designed for the production of a selected product family, which requires their concept to be built on the principles of reconfigurable manufacturing systems [7]. Competency islands can be imagined as cells that are capable of carrying out certain activities (competencies). Their task is to provide a service to the manufactured product so that after carrying out operations on several competency island the product is complete. The competency islands are not interconnected by any conveyor-like device. However, they have the ability to communicate with their surroundings. Product transport is provided by means of mobile robotic systems and mobile automated platforms. Agents shall cooperate with each other to follow their own objectives, with the emergent behaviour of the elements of the system. Manufacturing will appear to be in chaos, but at the digital level there will be a strict logic resulting in organised chaos. To Fig. 3 can see a comparison of the current classic automotive assembly line and the concept of competency islands.

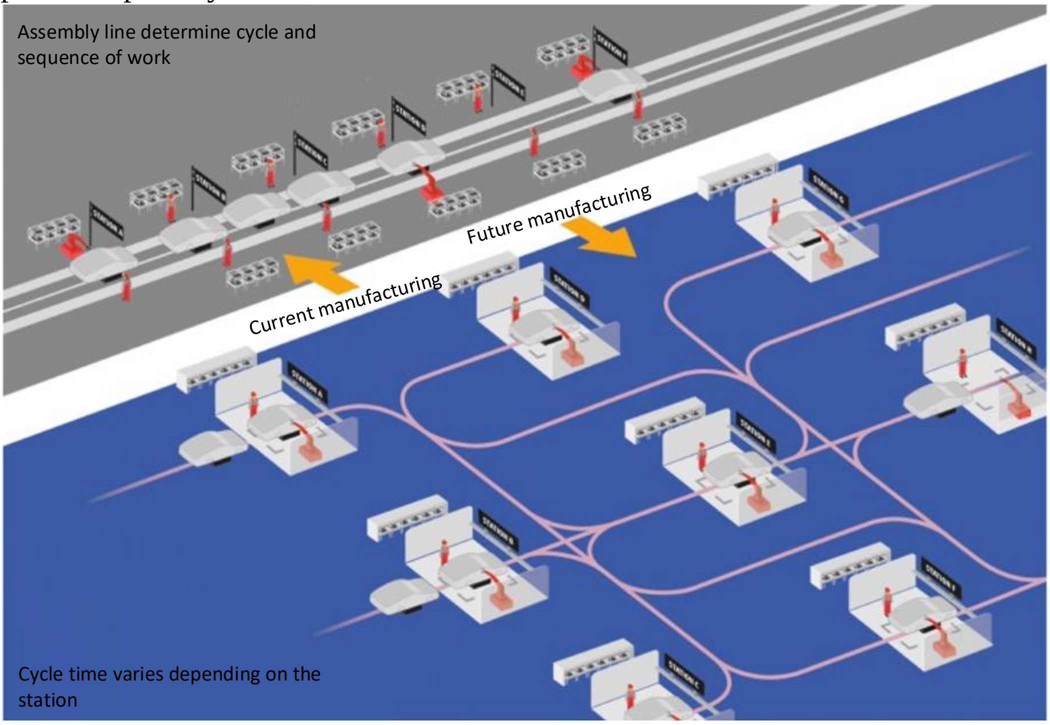


Fig. 3 Comparison of the current classic automotive assembly line and the concept of competency islands [8]

Conclusion

The value of the production lead times and assembly time of the product is an important indicator which suggests the efficiency of capacity utilisation. Maximising capacity utilisation at the lowest possible production costs and production lead times is part of a known production management relationship. Mainly in the automotive industry, with the high variation of the produced spectrum, capacity utilisation and the increase in production lead times are increasing. This is due to the impossibility of changing the order of the assembled car due to the fixed line layout. The idea of the competence islands is considering subsegregation of production and assembly processes into an island providing services where the product to which autonomy will be given under this concept chooses its route. The process of choosing a route is an approximate plan derived from rolling planning, but the final route will not be decided until the current status has been assessed. By removed of the fixed bound, the route which is created in certain point can be described as a virtual manufacturing line. By this way it can improve the efficiency of capacity utilisation and can be obtain reduce in production lead times.

Acknowledgments: "This work was supported by the KEGA Agency under the contract no. KEGA 020ŽU-4/2019”.

References
[1] GABAJOVÁ, G., FURMANNOVÁ, B., MEDVECKÁ, I.: Use of augmented and virtual reality in industrial engineering. In: Trendy a inovatívne prístupy v podnikových procesoch : zborník príspevkov. - Košice: Technická univerzita v Košiciach. pp. 36-42. ISBN 978-80-553-3422-6. (2019) on-line
[2] FUSKO, M., BUČKOVA, M., KRAJČOVIČ, M., SVITEK, R.: The strategy for implementation of the digitization in factories. 13th International Scientific Conference on Sustainable, Modern and Safe Transport (TRANSCOM), MAY 29-31, 2019, Novy Smokovec, Slovakia, Vol. 40, pp. 1045-1052, 2019, DOI: 10.1016/j.trpro.2019.07.146
[3] GREGOR, M., MIČIETA, B., BUBENÍK, P.: Plánovanie výroby, SLCP, Žilinská univerzita v Žiline EDIS, 2005, ISBN 80-8070-427-9, pp. 173.
[4] PEKARČÍKOVÁ, M., TREBUŇA, P., EDL, M., ROSOCHA, L.: Vplyv industry 4.0 na transformáciu logistiky na logistiku digitálnu. In: Trendy a inovatívne prístupy v podnikových procesoch : zborník príspevkov. - Košice: Technická univerzita v Košiciach. pp. 140-145. ISBN 978-80-553-3422-6. (2019) on-line
[5] GRZNÁR, P.: Modelovanie a simulácia procesov v budúcich továrňach: Žilinská univerzita v Žiline, habilitation thesis, 2019, pp. 158
[6] FUSKO, M., BUČKOVÁ, M., GAŠO, M., KRAJČOVIČ, M., DULINA, Ľ., SKOKAN, R. Concept of Long-Term Sustainable Intralogistics in Plastic Recycling Factory. Sustainability 2019, 11, 6750.
[7] GREGOR, M., et al.: Budúce továrne - Technologické zmeny a ich vplyv na budúce výrobné systémy. Žilinská univerzita v Žiline, CEIT, a.s., pp. 46, 2017, ISBN 978-80-89865-01-7
[8] PRODUKTION. Available on-line: https://www.produktion.de/trends-innovationen/das-ende-des-fliessbands-306.html (01.10.2020)

Contact address
Ing. Štefan Mozol
University of Žilina, Faculty of Mechanical Engineering, Department of Industrial Engineering, Univerzitná 8215/1, 010 26 Žilina, Slovakia
e-mail: stefan.mozol@fstroj.uniza.sk

Review process
Single-blind peer review process.

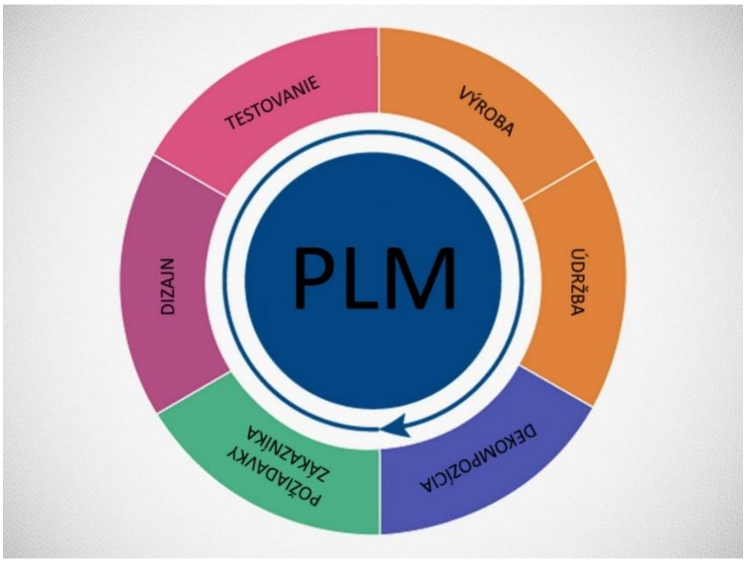
IMPLEMENTÁCIA PLM SYSTÉMOV AKO PRVÝ KROK K PRECHODU NA INDUSTRY 4.0

Radim LENORT – Marek KLIMENT – Ján KOPEC – Ladislav ROSOCHA

Abstrakt: V 21. storočí je každým dňom stále väčší problém udržať podnik na konkurencieschopnej úrovni. Podniky sa modernizujú, väčšinu práce vykonávajú roboti, pretože sú presnejší a spoľahlivejší ako personál. Ak chce podnik vytvoriť produkt, ktorý bude mať najhodnotnejšie vlastnosti pre zákazníkov, musí využívať PLM softvérové prostriedky na čoraz vyššej úrovni. Je dôležité vedieť aký produkt podnik bude vyrábať, aké bude mať vlastnosti, aké stroje sa využijú v procese výroby. Príspevok sa zaoberá problematikou implementácie PLM systémov do podnikových procesov a ich následnom využití pri digitalizácii týchto procesov ako základ k prechodu podnikov ku koncepcii Indystry 4.0
Kľúčové slová: PLM systémy, Digitalizácia, Simulácia, Industry 4.0

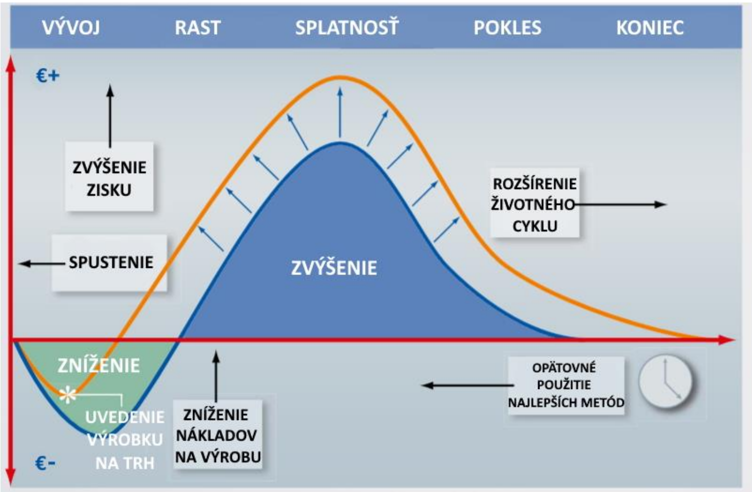
Úvod

Výhodou využívania PLM v procese výroby je hlavne prehľadnosť. Podnik aby bol schopný stále lepšie vyrábať je nútený poznať informácie o procesoch, ktoré sa vykonávajú na jednotlivých strojoch. Ak pozná tieto dáta, je možné ich využívať, analyzovať, editovať a využiť pre optimalizáciu procesov. Ak sú PLM systémy nasadené v organizácii komplexne a je zabezpečená ich prepojenosť a následná efektívna správa dát and všetkými jej časťami vzniká komplex digitálnych dát, ktoré je možné uplatniť v rôznych oblastiach riadenia, plánovania a kontrolovania v organizácii.
PLM (Product lifecycle management) je činnosť podniku, ktorá je zameraná na čo najužitočnejšie riadenie produktov danej spoločnosti. PLM zahrňuje všetky činnosti spojené s výrobou produktov, od ich prvotnej vízie aké vlastnosti by produkt mal mať a aké funkcie by mal byť schopný vykonávať cez testovanie, výrobu, údržbu, až po jeho úplné opotrebenie a likvidáciu (Obr.1).



Obr. 12 Cyklus PLM

PLM je systém, ktorý podniky využívajú pri riadení podnikových produktov. V podniku nie je nič dôležitejšie ako jej produkty a spôsob akým sa budú vyrábať a využívať. Bez podnikových produktov nebudú žiadni zákazníci a tým pádom ani príjmy. Okrem PLM sú aj iné prístupy k riadeniu produktov počas ich celého životného cyklu, ale sú tvorené viacerými systémami. PLM Predstavuje ucelený systém, ktorý je kompatibilný s viacerými modulmi, ktoré podnik využíva. Zaisťuje správne využívanie potrebných informácií, ako sú údaje obsiahnuté v CAD výkresoch, technickej dokumentácií a taktiež aj systémové informácie, ktoré sa postupom času a vývojom produktu menia, prenášajú, vytvárajú, ukladajú a prevádzkujú počas celej životnosti produktu.
Každý podnik sa v dnešnej dobe snaží skrátiť časový harmonogram vývoja nových produktov, ale na druhej strane znásobiť počet ponúkaných variantov vyrábaných produktov. Prepojenosť naprieč podnikom, cez výrobné haly s partnermi v reálnom čase a mieste kde je to nevyhnutné, vyžaduje stále dynamickejšie procesy, ktoré vyžadujú od podniku prispôsobivosť a dostatočnú flexibilitu. Predpokladá sa, že správne nástroje, technológie a tiež normy, ak sú správne využívané a zavedené do výrobného procesu a do samotného životného cyklu výrobkov, umožňujú podnikom zvyšovať ich konkurencieschopnosť a viesť ich k pozoruhodným zlepšeniam.
Úloha, ktorej čelí samotný systém PLM spočíva v tom zabezpečiť zainteresovaným stranám potrebné informácie, ktoré im uľahčia rozhodovanie a znížia administratívnu efektívnosť. PLM musí umožniť časové rozhranie pre zainteresované strany, komponenty a procesy. Motiváciou pre podniky aby využívali čo najefektívnejšie systém PLM je podrobnejšie porozumenie celého produktového systému, zlepšenie rozhodovacích činnosti podniku a formálnejší prístup k potrebným informáciám v rámci vývojového procesu, zvýšiť zisky z výroby výrobkov, znížiť náklady spojené s výrobou, vylepšiť hodnotu produktového portfólia a dosiahnuť vrcholnú užívateľskú hodnotu vyrábaných výrobkov a taktiež aj budúcich produktov pre zákazníkov a vedenie podniku (Obr.2).



Obr. 13 Nárast ziskov zavedením vysokej úrovne PLM

Fázy PLM

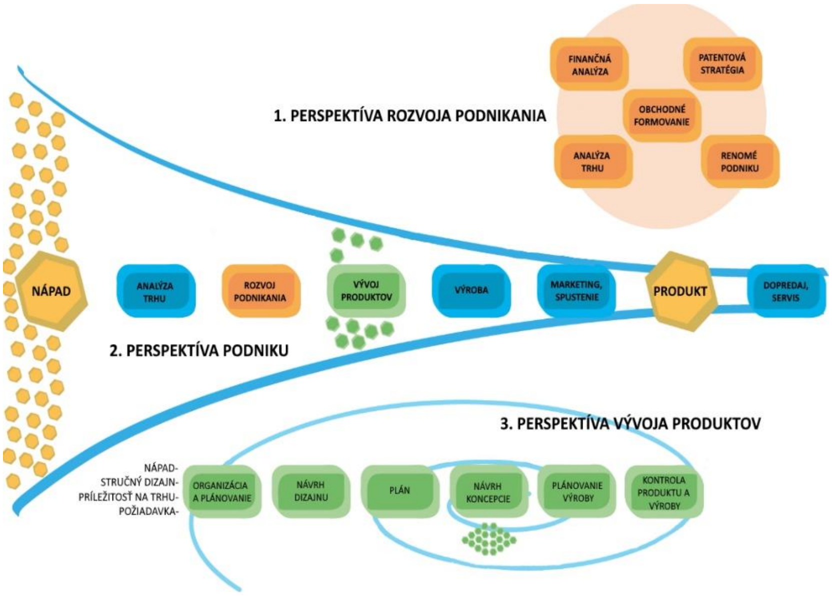
V životnom cykle produktu existuje 5 fáz:

- fáza vývoja,
- definičná fáza,
- realizačná fáza,
- podporná fáza a fáza používania,
- fáza vyradenia.

V každej z týchto fár životného cyklu produktu je výrobok v inom stave.

Fáza vývoja

Je to prvá fáze celého životného cyklu produktu. Produkt v tejto fáze sa nenachádza vo fyzickej forme, ale zatiaľ je len na teoretickej úrovni. V podniku riešia ako bude produkt vyzerať, aké bude mať vlastnosti, aké postupy pre výrobu budú použité a mnohé iné faktory. Základom v tejto fáze je aj názor zákazníkov, trhu, spoločnosti a regulačných orgánov. Spojením všetkých získaných poznatkov je možné definovať technické parametre výrobku. Súbežne sa v tejto fáze vykonáva aj úvodná koncepcia, ktorá definuje vzhľad produktu a zároveň aj hlavné funkčné vlastnosti. Táto fáza je tvorená od jednoduchých náčrtov perom až po zložité 3D modely. Z hľadiska rozvoja podnikania sa podnik musí pri fáze vývoja zaoberať aj finančnou analýzou, vývojom podnikania, analýzou trhu, patentovou stratégiou a menom podniku (Obr.3).



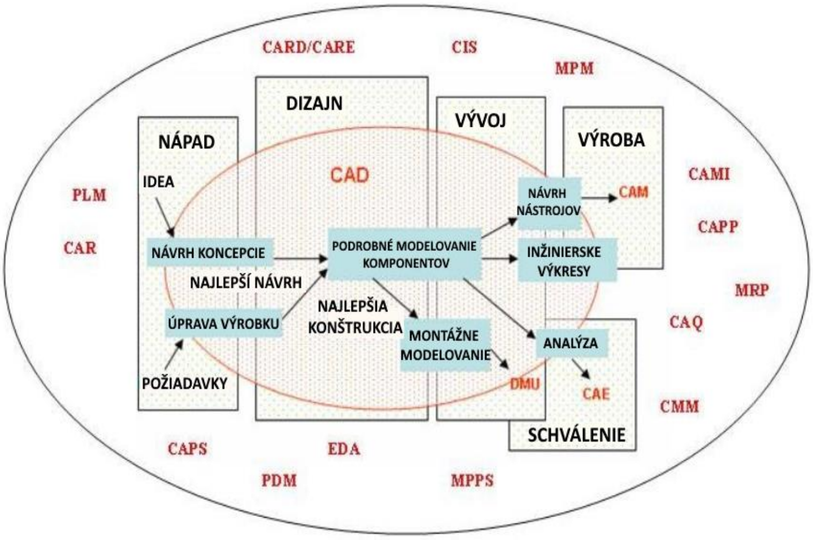
Obr. 14 Vývoj produktu a rozvoj podnikania

Definičná fáza

V tejto fáze sa začína riešiť podrobnejší návrh a vývoj finálnej formy produktu, testovanie prototypov a to od základného vydania až po úplne uvedenie produktu na trh. Patrí sem aj prepracovanie a vylepšenie už existujúcich produktov a ich plánované opotrebenie. Základným zdrojom informácií pre vývoj a návrh v tejto fáze životného cyklu predstavujú CAD výkresy. Jedná sa o jednoduché 2D výkresy až po 3D parametrické modelovanie objektov, resp. plôch. V mnohých prípadoch sa využívajú aj hybridné modelovanie, reverzné inžinierstvo, nedeštruktívne testovanie a konštrukcia zostavy aby bolo zaistené najoptimálnejšie vlastnosti produktu. Simulácia a optimalizácia sa vykonáva pomocou softvérov CAE, ktoré sa využívajú na vykonávanie stresovej analýzy, analýza konečných prvkov, simulácia mechanických udalosti. CAQ, sa využíva na analýzu menšej tolerancie.

Realizačná fáza

Po ukončení návrhu komponentov výrobku je definovaný spôsob akým sa bude product vyrábať. Realizačná fáza v sebe zahŕňa CAD, ako sú dizajn nástrojov, vytváranie pokynov a posuvov CNC obrábacích centier pre jednotlivé produktové súčasti. Využíva sa integrovaný alebo samostatný výrobný softvér s podporou CAM, ktorý zahŕňa analytické nástroje na simuláciu procesu pre výrobných operáciách, ako sú odlievanie, formovanie, formovanie pod tlakom a pod. Do chodu sa dostáva taktiež aj, ktoré zahŕňa nástroje ako CAPE, CAP a simuláciu výroby. Po procese výroby produktov je možná kontrola geometrického tvaru a rozmerov pomocou pôvodných CAD dát. Súbežne s inžinierskymi úlohami sa vykonáva aj konfigurácia produktu a marketingová dokumentácia (Obr.4).



Obr. 15 Prepojenosť počítačom podporovaných systémov a PLM fáz

Podporná fáza a fáza používania

Počas podpornej fázy a fázy používania produktu zákazník využíva výrobok podniku. V tejto fáze podnik ponúka pre zákazníka správu o prevádzkových informáciách, napr. informácie o opravách a údržbe zákazníkom ale aj poskytovateľom služieb technickej podpory produktu, manuál k správnej manipulácií, bezpečnostne požiadavky .

Fáza vyradenia

Fáza vyradenia je posledná fáza životného cyklu produktu kedy už produkt pre zákazníka nevytvára žiadnu pridanú hodnotu a je nepoužiteľný, resp. je stále použiteľný, ale s vysokým stupňom opotrebenia a pre zákazníka je výhodnejšie zakúpenie nového modelu. V tejto fáze podnik ponúka informácie o recyklácií produktu. Každý produkt má špeciálne vlastnosti, preto je potrebné zvážiť jeho zneškodnenie, zničenie materiálových predmetov alebo informácií, pretože unáhlené zničenie môže mať vážne následky.

PLM softvérové prostriedky

Presné modelovanie produktov v digitálnom prostredí, 3D vizualizácia a simulácia prinášajú výhody pre podnik pri riešení problémov spojených s vývojom, vizualizáciou a analýzou výrobných procesov. Správne vyhodnotenie umožňuje vykonávať kľúčové rozhodnutia včas, tým sa eliminujú chyby, ktoré by inak boli zistené až v procese výroby. Včasnou elimináciou chýb je podnik schopný zvýšiť svoju produktivitu, kvalitatívne bude produkt na vyššej úrovni, celý proces sa zrýchli, príjmy z predaja výrobku budú vyššie a v neposlednom rade bude zabezpečená centralizovaná správa údajov.

Benefity využívania špičkových softvérových prostriedkov:

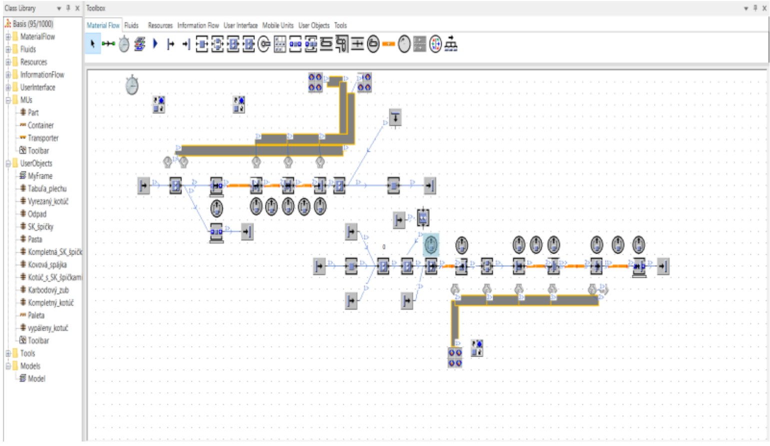
- Jednoduché použitie,
- Integrácia systému,
- Správa materiálových listov,
- Riadenie zmien,
- Predloženie správ a analytika,
- Manažment kvality,
- Spolupráca s dodávateľom,
- Manažment výrobných dát,
- Podpora existujúcich procesov,
- Flexibilita a dostupnosť,
- Rýchlosť implementácie,
- Zaistenie ochrany životného prostredia,
- Varovanie pred nevyhovujúcimi materiálmi.

Digitalizácia a vizualizácia procesov

Jedným z vrcholných prvkov v oblasti PLM je tvorba simulačných modelov celých výrobných systémov. Pokiaľ máme vypracované 3D modely zariadení a produktov, ktoré budú zahŕňať plánovaný výrobný proces, je možno tento proces premietnuť do digitálnej podoby a vytvoriť jeho hodnovernú vizualizáciu. Pri tvorbe simulačných modelov je možné uplatniť všetky poznatky, ktoré o produkte v rámci životného cyklu máme. Taktiež je vhodné pri ich spracovaní využiť všetky poznatky a parametre zariadení, ktoré sú nám známe. Čím viac informácii o výrobnom procese je k dispozícii, tým presnejšie modely je možné vytvoriť. Údaje získané z takýchto modelov je možno následne reanalizovať a vyhodnotiť realizovateľnosť podnikateľských zámerov, prípadne ich prispôsobiť možnostiam, ktoré plánovaná výroba na základe výsledkov simulácie ponúkne.

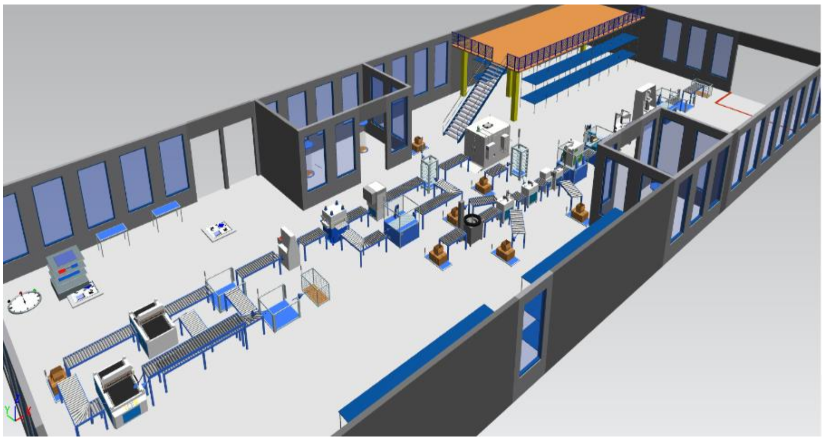
Možnosti simulačných procesov

Simulačné softvéry ponúkajú viacero možností ako zobrazovať realitu, ktorá je do nich prenesená. Ide o detailnosť a presnosť dát prenesených z reálneho do virtuálneho sveta. Väčšina softvérov má možnosť zobrazovať modely v 2D vizualizačnom rozhraní (Obr. 5). Pri takomto zobrazení je možné využiť stavebné výkresy znázorňujúce pôdorysy výrobných priestorov a rozmiestnenie jednotlivých zariadení v nich. Pre názornosť sme využili simulačný softvér Tecnomatix Plant Simulation a jeho možnosti.



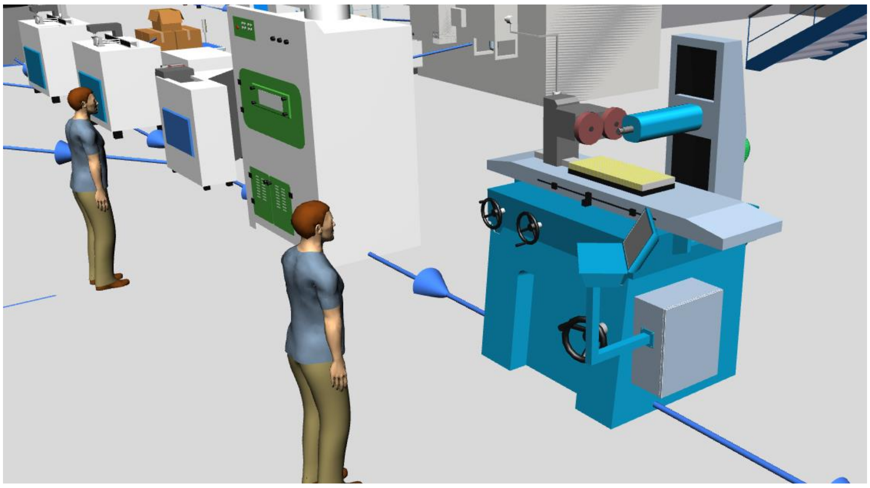
Obr. 16 Zobrazenie simulačných modelov v 2D rozlíšení

Ďalším oveľa názornejším spôsobom vizualizácie výrobných systémov je využitie 3D zobrazenia v simulačných softvéroch. Opäť sme využili softvér Tecnomatix Plant Simulation. Tento softvér okrem svojho základného zobrazenia prvkov využívaných pre tvorbu procesov umožňuje tieto základne prvky nahradiť vlastnými detailnejšími modelmi výrobných zariadení. Takýmto spôsobom umožňuje vytvárať reálnejšie predstavy simulovaných výrobných systémov (Obr. 6).

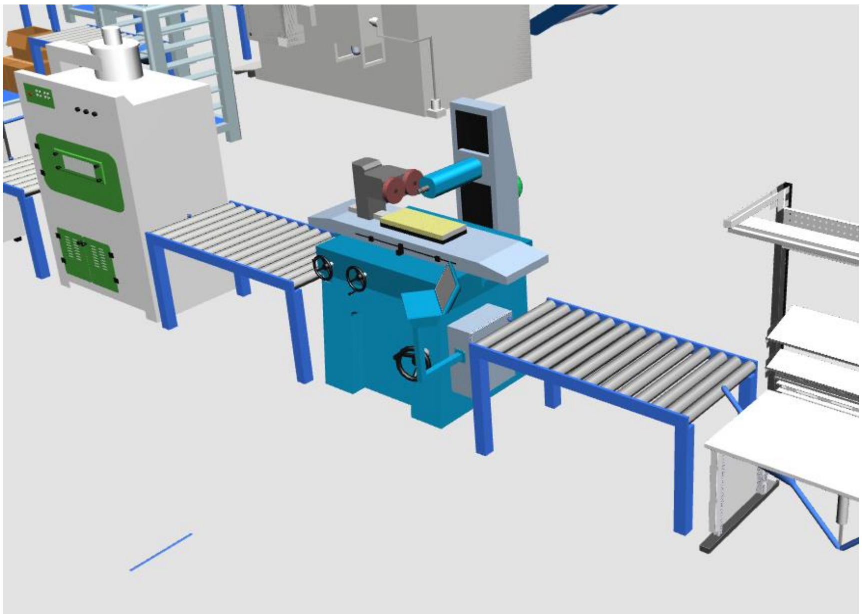


Obr. 17 3D realizácia výrobnej haly s vlastnými modelmi strojov

V tomto ako aj v iných simulačných softvéroch je možné overovať a vyhodnocovať jednoducho a úsporne rôzne výrobné varianty. Je možné simulovať ľudí a ich činnosť priamo vo výrobnom procese (Obr.7). Je tiež možné overovať, či je výhodnejšie využitie ľudského faktoru pri manipulácii a medziobjektovej logistike, alebo je výhodnejšie využitie manipulačných zariadení ako sú dopravník, vozíky a podobne (Obr.8).



Obr. 18 Ľudia v simulácii výrobných systémov



Obr. 19 Manipulátory v medziobjektovej doprave

Spracovanie simulačných modelov, digitalizácia všetkých produkčných procesov a implementácia všetkých dostupných faktorov a informácii v nich je prvým krokom k možnosti nástupu prvkov Industry 4.0. Práve proces digitalizácie umožňuje využitie moderných nástrojov, akými sú napríklad TestBed 4.0. Digitalizácia výrobných procesov tvorí základný kameň pre nástup a implementáciu koncepcie Industry 4.0 do praxe.

Záver

PLM systémy a ich schopnosti údaje prehľadne archivovať, spravovať a vhodne editovať na všetkých rôznych úrovniach organizácie, kľúčovým faktorom pre nástup moderných technológii budúcnosti, akými sú nástroje koncepcie Industry 4.0. Okrem týchto systémov je v tejto novej idei potrebné zabezpečiť vhodný spôsob komunikácie medzi jednotlivými úrovňami riadenia a fungovania organizácii, či už v internom, alebo externom prostredí na globálnom trhu. Konkurencieschopnosť je možné si udržať len tým, že organizácie včas pochopia ideu modernizácie svojich procesov v každom ohľade. Reakcia na je nástup musí byť integrovaná a komplexná, zahŕňajúca všetky zúčastnené strany na globálnom základe od verejného do súkromného sektora, do akademickej obce i do občianskej spoločnosti. Táto filozofie prinesie inovácie vo všetkých ohľadoch fungovania organizácii, či už ide o ekonomiku, ľudské zdroje, vedenie spoločností, výrobné faktory a iné systémy, bez ktorých organizácia fungovať nedokáže.

Poďakovanie

Príspevok vznikol za pomoci grantových projektov: VEGA 1/0438/20 Interakcia digitálnych technológií za účelom podpory softvérovej a hardvérovej komunikácie pokročilej platformy systému výroby, KEGA 001TUKE-4/2020 Modernizácia výučby priemyselného inžinierstva za účelom rozvoja zručností existujúceho vzdelávacieho programu v špecializovanom laboratóriu, APVV-17-0258 Aplikácia prvkov digitálneho inžinierstva pri inovácii a optimalizácii produkčných tokov, APVV-19-0418 Inteligentné riešenia pre zvýšenie inovačnej schopnosti podnikov v procese ich transformácie na inteligentné podniky.

Použitá literatúra

[1] EDL, M., LERHER, T., ROSI, B.: „Energy efficiency model for the mini-load automated storage and retrieval systems". International Journal of Advanced Manufacturing Technology, č. 2013, s. 1-19. ISSN: 0268-3768, (2013)
[2] GREGOR, M.; HERCKO, J.; GRZNAR, P (2015) The Factory of the Future Production System Research: 2015 21st International Conference on Automation and Computing
[3] FUSKO, M.; BUCKOVA, M.; GASO, M.; KRAJCOVIC, M.; DULINA, L.; SKOKAN, R. (2019) Concept of Long-Term Sustainable Intralogistics in Plastic Recycling Factory: Sustainability, Vol.: 11, Issue: 23, Art. No.: 6750, doi: 10.3390/su11236750
[4] FEDORKO, G.; MOLNÁR, V.; HONUS, S.; NERADILOVÁ, H.; - KAMPF, R. (2018) The application of simulation model of a milk run to identify the occurrence of failures: International Journal of Simulation Modelling = IJSIMM. - Wolkersdorf im Weinviertel, DAAAM International Vienna Vol. 17, No. 3 (2018), s. 444-457 [print]. - ISSN 1726- 4529
[5] MANLIG, F.; SLAICHOVA, E.; KOBLASA, F.; VAVRUSKA, J.(2014) Innovation of business processes by means of computer-aided simulation: Novel Trends In Production Devices And Systems, Applied Mechanics and Materials, Volume: 474, Pages: 67-72, doi: 10.4028/www.scientific.net/AMM.474.67.
[6]STRAKA, M., MALINDŽÁKOVÁ, M., TREBUŇA,P., ROSOVÁ, A.,PEKARČÍKOVÁ, M., FILL, M.: Application of EXTENDSIM for improvement of production logistics' efficiency, International Journal of Simulation Modelling. Vol. 16, no. 3 (2017), p. 422-434. - ISSN 1726-4529

Contact address

Ing. Marek Kliment, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: marek.kliment@tuke.sk

Review process

Single-blind peer review process.

POROVNANIE VYBRANEJ BEZKONTAKTNEJ 3D TECHNOLÓGIE

Milan EDL – Marek MIZERÁK– Jozef TROJAN– Richard DUDA

Abstrakt: Tento príspevok sa zaoberá problematikou bezkontaktného 3D skenovania a tiež porovnaním dvoch skenovacích zariadení, ktoré sa používajú na vzdelávacie účely. Skenery, ktoré boli porovnávané, sú skener Matter & Form a Sense 3D skener. Skeneri, ktoré budú porovnávané sú využívane v rámci edukácie na Ústave manažmentu, priemyselného a digitálneho inžinierstva. V článku budú definované ich základné parametre, podrobne popísané jednotlivé skenery a zistené ich výhody a nevýhody. Na konci článku budú tieto skenovacie zariadenia vyhodnotené z hľadiska niekoľkých kritérií.

Kľúčové slová: 3D skener, 3D skenovanie, bezkontaktná technológia

Úvod

S príchodom počítačovej techniky bolo možné vytvoriť veľmi zložitý model, problém však nastal pri jeho výrobe. V 80. rokoch sa preto vytvorila kontaktná sonda. Tá umožnila vytvorenie presného modelu, čo však bolo náročné na čas. Samozrejme, vznikla myšlienka vytvorenia systému, ktorý by dokázal zachytiť tieto presné detaily v kratšom čase, čo by zefektívnilo použitie. To spustilo vývoj optickej technológie. Používanie svetla bolo niekoľkonásobne rýchlejšie ako použitie fyzickej kontaktnej sondy. Použitie optickej technológie umožnilo aj skenovanie predmetov z mäkkých materiálov, ktoré by sa kontaktnou technológiou mohli poškodiť. Bezkontaktná laserová technológia sa stala hlavnou technológiou 3D skenovania, ale čoskoro sa ukázalo, že skutočnou výzvou pre skenovanie bol softvér na spracovanie získaných údajov. Na zachytenie skutočného objektu v troch rozmeroch senzor vykonal niekoľko skenov z viacerých pozícií. Výzvou bolo spojiť tieto skeny do jednej jednotky a eliminovať duplicitné a nadbytočné údaje, čo nevyhnutne vzniká pri zbere údajov niekoľkých miliónov bodov naraz.

Bezkontaktná 3D technológia

Ako naznačuje názov, bezkontaktné technológie 3D skenovania neprichádzajú do fyzického kontaktu s povrchom skenovaného objektu. Namiesto toho fungujú bezkontaktné technológie na základe aktívnych a pasívnych techník skenovania objektov. Výsledkom je zhluk vysoko presných bodov, ktoré možno použiť na reverzné dešifrovanie, virtuálne zostavenie, štrukturálnu analýzu, kontrolu povrchov a prvkov alebo rýchle prototypy.
3D skenovanie má svoje miesto v architektúre pri obnove a rekonštrukcií starých miest alebo predmetov. V budúcnosti si určite svoje miesto nájdu aj v medicíne v protetike alebo ako pomoc pre hendikepovaných ľudí – konkrétne pri reprodukcií nahradzovaných častí ľudského tela. Pomocou 3D skeneru je rovnako veľmi jednoduché porovnať vyrobenú súčiastku v sériovej výrobe s plánom, rovnako v geografií pri tvorbe máp, ale aj v zábavnom priemysle.

Tab.1 Porovanie parametrov jednotlivých skenerov

		3D SENSE	MATTER & FORM
Veľkosť skenera	Výška	17,8 cm	34,5 cm
	Šírka	3,3 cm	21 cm
	Dĺžka	12,9 cm	34,5 cm
	Hmotnosť	0,5 kg	1,71 kg
Presnosť skenera		± 1 mm	± 0,1 mm
Rozmery skenovaného objektu	Max. veľkosť	300x300x300 cm	25x18x18 cm
	Min. veľkosť	20x20x20 cm	1x1x1 cm
	Max. hmotnosť	-	3 kg
Pripojenie		USB 3.0	USB 2.0/3.0
Napájanie		USB 3.0	100 – 240 V
Prevádzková teplota		10 – 40 °C	15 – 32 °C
Softvér		3D Systems Sense	MFStudio (+Quickscan)
Podporované platformy		Windows 8, 8.1, 10 (64 bit)	Windows 7, 8, 8.1, 10 (64 bit), macOS 10.11+
Cena		± 525 €	± 730 €

3D skener Matter & Form

3D skener od firmy Matter & Form predstavuje v pravom slova zmysle 3D skener pre bežného užívateľa. Jeho cenová dostupnosť a jednoduchá manipulácia sú mostom medzi profesionálnym a amatérskym 3D skenovaním. Jeho kompaktnosť sa samozrejme nezaobíde bez určitých obmedzení ako je napríklad veľkosť a hmotnosť skenovaných objektov. Presnosť skenovania je vzhľadom na cenu skenera viac než uspokojivá, avšak táto skutočnosť sa prejavuje na čase skenovania. Dĺžka skenovania objektu zložitejších tvarov a detailov sa približuje k hranici 60 minút.

Obr.1 Skener Matter & Form

3D skener SENSE

Sense 3D skener je cenovo dostupný ručný 3D skener s relatívne vysokou presnosťou skenovania, ktorá avšak značne závisí od kvality osvetlenia skenovaného objektu, a od jeho veľkosti. Výrobca v špecifikácií totiž udáva aj minimálnu veľkosť skenovaného objektu. Menšie objekty skener nie je schopný reálne zachytiť. Jeho kompaktnosť je veľkou výhodou, no doplatila na to dĺžka kábla pre napájanie, čo v značnej miere obmedzuje manipuláciu so skenerom.

Obr.2 Skener SENSE

Hodnotenie použitej technológie skenovania

Dostupnosť
Kritérium dostupnosti v značnej miere vplýva na celkové zhodnotenie skenerov. V prípade, že obstaranie skenera predstavuje značne komplikovaný proces, vo výraznej miere ovplyvňuje tento faktor dosiahnutie finálneho modelu. Toto kritérium zahŕňa cenovú dostupnosť a celkovú dostupnosť. Celková dostupnosť predstavuje dostupnosť konkrétneho skenera na trhu. Cena skenera Sense 3D predstavuje približne čiastku 525 €, cena skenera Matter & Form predstavuje približne čiastku 730 €. Je očividné, že Sense 3D predstavuje pre užívateľa menšie finančné zaťaženie. Matter & Form svoju horšiu cenovú dostupnosť kompenzuje lepšou celkovou dostupnosťou. Podporuje ju fakt, že skener Matter & Form má v sortimentoch online predajcov výrazne väčšie zastúpenie.

Manipulácia
Kritérium manipulácie predstavuje v akej miere je činnosť s konkrétnym skenerom náročná. Za predpokladu, že je vykonávanie operácií so skenerom jednoduché a intuitívne, bude skener v tomto kritériu hodnotený pozitívne. Skener Sense 3D má náramne jednoduchú prípravu na činnosť skenovania, ako je už spomínané v kapitole 2. Avšak pri samotnej činnosť skenovania je potrebné, aby sa užívateľ sústredil a s veľkou presnosťou venoval skeneru. Túto náročnosť je podľa nášho názoru možné v značnej miere zjednodušiť využitím statívu. Skener Matter &

Form má naopak zložitý proces prípravy, no samotná činnosť skenovania si takmer nevyžaduje užívateľovu pozornosť. Užívateľ pred začatím skenovania nastaví všetky parametre činnosti, ktoré skener následne vykoná samostatne.

Možnosti nastavenia skenovania

Kritérium hodnotenia možností nastavenia skenovania sa zapodieva škálou možností, ktoré nám jednotlivé softvéry skenerov ponúkajú pred samotnou činnosťou. V kapitole 2 sme sa venovali prostrediu používaných softvérov, kde sme si objasnili ich funkcie. Toto kritérium nezohľadňuje iba množstvo funkcií, ktoré softvér ponúka, ale aj ich účinnosť na samotnú činnosť skenovania. Skener Sense 3D nám pred samotnou činnosťou vytvárania digitálneho modelu neponúka veľký výber možností. Väčšina nastavení sa týka samotného prostredia softvéru. Samotné skenovanie ovplyvňuje výber typu objektu, ktorý nám ponúka iba 3 možnosti. Tento fakt však predstavuje pre nového užívateľa výrazné zníženie komplikácií s obsluhou skenera. Skener Matter & Form nám ponúka výrazne väčšie množstvo možností. Každá z týchto možností výrazne ovplyvní priebeh skenovania ako aj dosiahnutý digitálny model objektu. Množstvo týchto funkcií značne predĺži čas, ktorý bude potrebný pre schopnosť nového užívateľa využívať plný potenciál tohto skenera.

Časová náročnosť

Časová náročnosť je kritériom, ktoré bude mať signifikantný význam hlavne na strane užívateľa. Podstatný faktor predstavuje priemerný čas od samotnej prípravy až po kompletný digitálny model objektu. Skener Sense 3D by sme v tejto oblasti mohli popísať ako výrazne dynamický 3D skener. Skenovanie všetkých testovaných objektov nám v žiadnom z prípadov netrvalo viac ako 30 minút. K tejto skutočnosti prispievajú jeho intuitívne ovládanie a nenáročnosť nastavení samotného skenovania. Skener Matter & Form výrazne stráca na dynamike v porovnaní so skenerom Sense 3D. Samotná príprava predstavuje zdĺhavý proces. Časovú náročnosť negatívne ovplyvňuje aj skutočnosť veľkého množstva výberu možností. Každé z týchto nastavení má vplyv na trvanie skenovania, ktoré nám softvér signalizuje zobrazením odhadovaného času skenovania.

Obr.3 Modely na ktorých boli skenery testované

Poďakovanie

Tento článok bol vytvorený realizáciou grantových projektov VEGA 1/0438/20 Interakcia digitálnych technológií za účelom podpory softvérovej a hardvérovej komunikácie pokročilej platformy systému výroby, KEGA 001TUKE-4/2020 Modernizácia výučby priemyselného inžinierstva za účelom rozvoja zručností existujúceho vzdelávacieho programu v špecializovanom laboratóriu, APVV-17-0258 Aplikácia prvkov digitálneho inžinierstva pri inovácii a optimalizácii produkčných tokov a APVV-19-0418 Inteligentné riešenia pre zvýšenie inovačnej schopnosti podnikov v procese ich transformácie na inteligentné podniky.

Záver

3D skenovanie je jednou z najpodstatnejších súčastí digitalizácie. Vytváranie kvalitného digitálneho 3D modelu a následná úprava v softvéroch vo výraznej miere ovplyvňuje kvalitu a rýchlosť tvorby inovácií. Efektívnym využívaním digitalizačných techník je možné dosahovať vynikajúce výsledky v oblasti inovácií.

Tento článok bol zameraný na vytvorenie porovnania dvoch bezkontaktných skenerov Matter & Form a Sense 3D, ktoré vlastní Ústav manažmentu, priemyselného a digitálneho inžinierstva. Skúmali sa podmienky ako dostupnosť, manipulácia, nastavenie skenovania a časová náročnosť. Pokiaľ ide o skúsenosti a celkový pohľad, stojí za to povedať, že v konečnom dôsledku je skener 3D SENSE je na vyššej úrovni ako skener Matter & Form čomu sa rovnali aj výsledné skeny.

Referencie

[1] EBRAHIM, Mostafa Abdel-Bary. 3D SCANNERS: HISTORY, APPLICATIONS, AND FUTURE [online]. ResearchGate, 10/2014. Available on: <https://www.researchgate.net/publication/267037683_3D_LASER_SCANNERS_HISTORY_APPLICATIONS_AND_FUTURE>

[2] VINESH, R.; KIRAN, F.: Reverse Engineering – An Industrial Perspective, Springer Science, London, 2008, ISBN 978-1-84628-855-5.

[3] 3D scanning technologies and the 3D scanning process [online]. 2020. available on: <https://www.aniwaa.com/guide/3d-scanners/3d-scanning-technologies-and-the-3d scanning-process/> .

[4] GRZNAR, P., GREGOR, M., MOZOL, S., KRAJCOVIC, M., DULINA, L., GASO, M., MAJOR, M.: A System to Determine the Optimal Work-in-Progress Inventory Stored in Interoperation Manufacturing Buffers, Sustainability, vol. 11, no. 14, 1-36, doi: 10.3390/su11143949, 2019.

[5] P. DULENČIN; školiteľ M. Tolnay , Vytváranie 3D modelov reálnych objektov digitálnou fotogrametriou : dizertačná práca. Košice, 2012. 117 s.

[6] The Future Of 3D Scanning And Its Impact On Industrial Quality Control [online]. 2017. Dostupné na internete: <https://www.manufacturing.net/industry40/article/13227099/the future-of-3d-scanning-and-its-impact-on-industrial-quality-control>.

[7] CVUT. 3D laserové skenování - teorie [online]. 2015. available on: <http://lfgm.fsv.cvut.cz/data/vvt/s1/laserteorie3d.pdf>.

[8] V2 3D Scanner [online]. available on <https://matterandform.net/scanner>.

Kontakntá adresa
Ing. Marek Mizerák.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: marek.mizerak@tuke.sk

Review process
Single-blind peer review process.

NÁVRH VIZUALIZAČNÉHO MODELU KONCEPTU TESTBED V PROSTREDÍ SOFTVÉRU SKETCH UP

Peter TREBUŇA –Marek MIZERÁK– Jozef TROJAN–Ladislav ROSOCHA

Abstrakt: Tento príspevok sa zaoberá možnosťou vytvorenia vizualizačného modelu alebo digitálneho dvojčaťa daného objektu v programe SketchUp.Tento program je známy pre širokú škálu modelovacích aplikácií. Tento program bol vybraný, pretože je dokonalým nástrojom na vizualizáciu objektov a je veľmi užívateľsky príjemný. Aplikácia nám tiež dáva slobodu vykonávať zmeny ľahko, čo najrýchlejšie a v oveľa väčšom počte
. Príspevok tiež popisuje jednotlivé prvky nachádzajúce sa vo vizualizačnom modeli a ich účel.
Kľúčové slová: vizualizácia, model, Sketch Up.

Úvod

V dnešnej dobe sa čoraz častejšie stretávam s pojmom vizualizácia. V modernom strojárstve je toto slovné spojenie neoddeliteľne spojene s Industry 4.0. Moderné výrobné spoločnosti kladú čoraz väčší dôraz na vytváranie modelov digitálnych spoločností a následné zvyšovanie efektívnosti výroby, a to nielen z ekonomického hľadiska.

Jedná sa o digitálne znázornenie fyzického objektu alebo systému. Technológia, ktorá stojí za digitálnym dvojčaťom, sa stala natoľko rozšírenou, že zahŕňa veľké predmety, ako sú budovy, továrne, mestá a dokonca aj ľudia alebo procesy môžu mať digitálne dvojčatá, čím sa tento koncept ďalej rozširuje. Berie do úvahy vstupy z údajov z reálneho sveta o fyzickom objekte alebo systéme a vytvára ich ako predpovede výstupov alebo simulácie toho, ako budú tieto vstupy ovplyvnené na fyzický objekt alebo systém. [1]

Technológia nám umožňuje skúmať a vyvíjať nové služby, aby sme uspokojili meniace sa potreby používateľov a prispôsobili im spôsob práce, života a používania technológií. [2]

Softvér na trojrozmerné modelovanie a animačné programy je možné použiť rôznymi spôsobmi na rôzne účely. Umožňujú vám navrhnúť svoje vlastné objekty umiestnené v priestore pomocou základných geometrických tvarov, ako sú gule, valce, kužele. Všetky tieto oddelenia potom tvoria celú scénu projektov. Takmer každý program má množstvo nástrojov potrebných na definovanie svojich vlastných objektov, od dvojrozmerných obrázkov až po ich konverziu do trojrozmernej podoby. K dispozícii je tiež možnosť modelovať základné objekty a manipulovať s nimi pomocou špeciálnych nástrojov.

Hlavnou témou tohto článku je vytvorenie 3D modelu konceptu TestBed v softvéri SketchUp.

Softvér Sketch Up

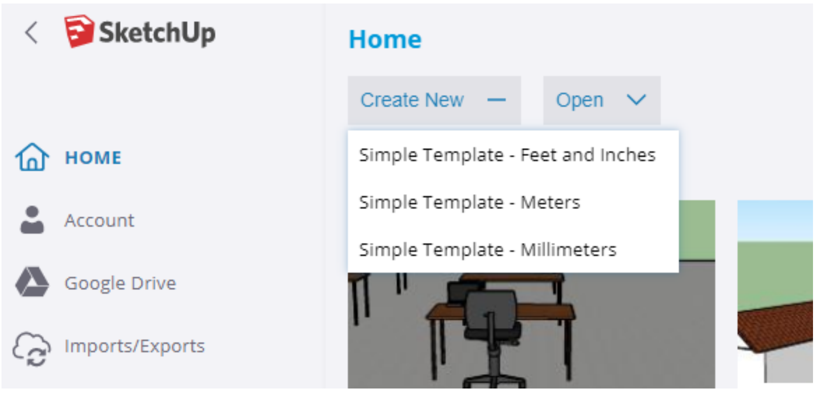
Sketchup, predtým známy pod menom Google Sketchup, je softvér na 3D modelovanie, ktorý sa ľahko používa a na stiahnutie je k dispozícii rozsiahla databáza modelov vytvorená používateľmi. Môže sa použiť na načrtnutie alebo importovanie modelov na pomoc so všetkými druhmi projektov ako je výstavba nábytku, tvorba videohier, 3D tlač, návrh interiéru a iné.

SketchUp je intuitívna aplikácia na 3D modelovanie, ktorá umožňuje vytvárať a upravovať 2D a 3D modely pomocou patentovanej metódy „Push and Pull“. Nástroj Push and Pull umožňuje

návrhárom vytlačiť akýkoľvek plochý povrch do trojrozmerných tvarov. Potrebné je iba kliknúť na objekt a potom ho začať ťahať, kým sa nebude užívateľovi páčiť to, čo vidí.
SketchUp je program, ktorý sa používa pre širokú škálu projektov 3D modelovania, ako sú architektonický dizajn, interiérový dizajn, krajinná architektúra a dizajn videohier. Program obsahuje funkčnosť rozloženia výkresu, vykreslenie povrchu a podporuje doplnky tretích strán z Extension Warehouse, tzv. knižnice komponentov. Aplikácia SketchUp je tiež využívaná pri vytváraní, zdieľaní alebo sťahovaní 3D modelov pre použitie s 3D tlačiarňami.

Modelovanie v prostredí softvéru Sketch Up

Najprv si vyberieme šablónu v metroch. Ihneď po výbere sa otvorí pracovný priestor SketchUp. Oblasť sa skladá zo štyroch hlavných častí, troch súradnicových osí a figúry. V ľavom hornom rohu je ponuka, názov modelu a tlačidlo s možnosťou uloženia súboru buď na Disk Google, alebo priamo do vášho počítača (obr. 1).



Obr.1 Úvodná obrazovka softvéru SketchUp

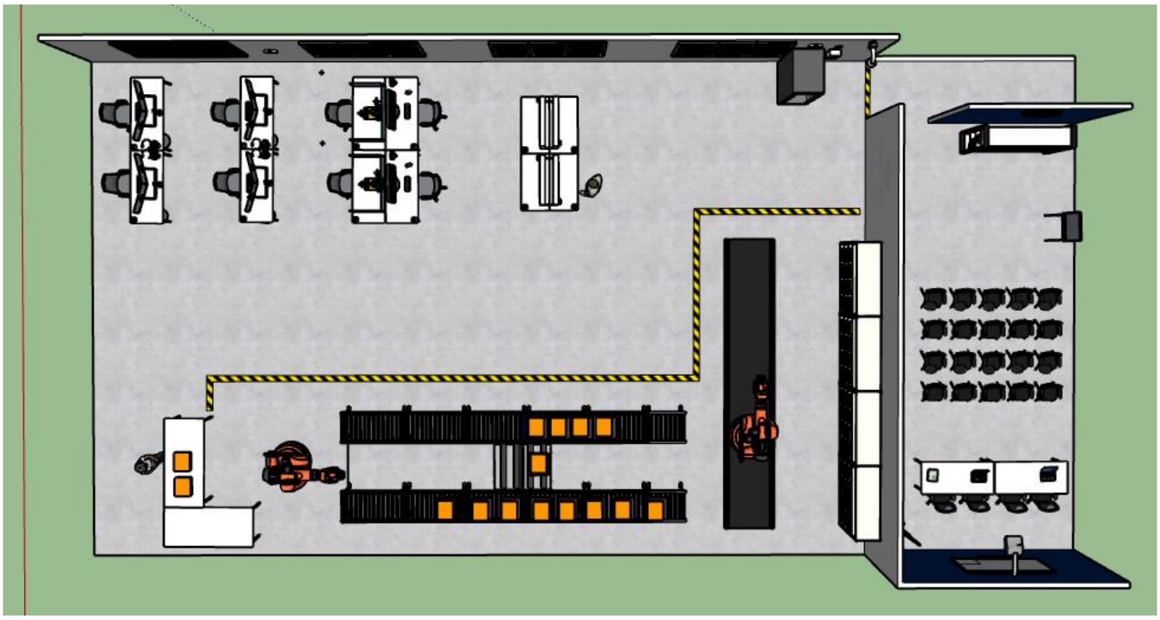
Na ľavej strane plochy sa nachádza panel so základnými nástrojmi. V pravom dolnom rohu sa nachádzajú rozmery tzv. „Measurements“, ktoré nám zobrazujú aktuálny rozmer daného objektu. Začiatočníci uvítajú inštruktora, nachádzajúceho sa na pravej strane obrazovky, ktorý napomáha, ako by sa mali jednotlivé nástroje ovládať a taktiež ponúka cenné klávesnicové skratky (Tab. 1).

Tab.1 Základné klávesové skratky

Function	Shortcut key
Select	Spacer
Eraser	E
Line	L
Arc	A
Rectangle	R
Circle	C

Push/Pull	P
Offset	F
Move	M
Rotate	Q
Scale	S
Tape Measure Tool	T
Paint Bucket	B
Orbit	O
Pan	H
Zoom Extents	Shift + Z

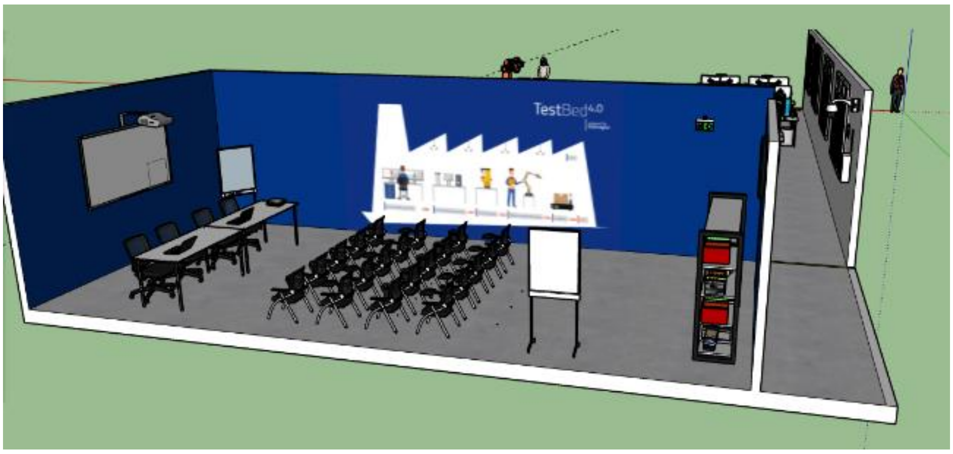
Začali sme výmerom plochy, a to 320 m2 (Obr.21). Na danej ploche sa nachádza testovacie pracovisko o ploche 250 m2 , edukačná miestnosť o ploche 60 m2 a prístupová chodba o ploche 10 m2.



Obr. 2 Plocha konceptu TestBed

Edukačná miestnosť

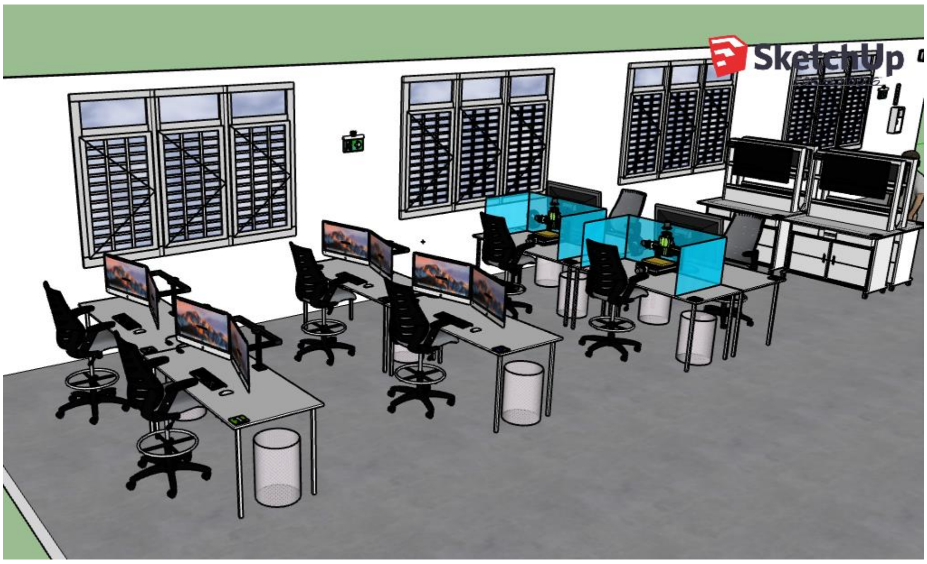
Edukačná miestnosť poskytuje priestory na výklad spojený s prezentáciou princípov a možností Industry 4.0. Je vhodná pre školenia, semináre, workshopy, kde slúži na prednášky či praktické cvičenia nielen pre študentov, ale aj pre top manažment. K dispozícii je projektor s tabuľou na prezentovanie a výklad danej témy, dve tabule na prípadne hlbšie vysvetlenie témy či rôzne nákresy. Vzadu sa nachádza menšia knižnica, ktorá slúži k lepšiemu porozumeniu témy či získaniu nových poznatkov, ktorú môžu návštevníci kedykoľvek využiť.



Obr. 3 Edukačná miestnosť

Testovacie pracovisko - TestBed

Hlavnou miestnosťou je testovacie pracovisko, ktoré sa skladá z dvoch častí. V prvej časti sa nachádzajú stoly s jednotlivými pracoviskami, kde každé pracovisko má na starosti niečo iné. Každý stôl je označený číslom, ktoré je následne priradené k činnosti, ktorú vykonáva. Jednotlivé pracoviská sú vybavené podľa toho, akú činnosť realizujú. Všetky prvky TestBedu, t.j. počítačové stanovištia a roboty, sú zosieťované a poprepájané.



Obr. 4 TestBed s jednotlivými pracoviskami

Na ploche sa nachádza sedem pracovísk (Obr.25). Pracovisko s číslom jedna má na starosti zberanie dát o výrobku, kde rieši komplexnú a čiastočnú integráciu podnikových procesov, zber, výmenu, spracovanie a vyhodnocovanie dát pre priemyselné podniky. Pracovisko číslo dva sa zaoberá vývojom a odladením automatizovaných zariadení. Predvýrobné fázy sa vykonávajú na pracovisku číslo tri. Pracovisko číslo štyri rieši výrobu, logistiku, manažérske výstupy (Obr.26). Pracovisko s číslom päť má dva stoly, obsahujúce CAM stroje. Na jednom z nich sa nachádza CAM stroj určený špeciálne na sústruženie, na druhom stole sa nachádza CAM stroj určený na frézovanie. Týmto pracoviskom sa po vložených vstupných údajoch, resp. parametroch stroja, dajú overiť podmienky, ktorými by podliehal daný obrábací stroj v reálnej výrobe. Takýmto spôsobom sa dá na tomto pracovisku otestovať efektívnosť zariadení vo výrobných podnikoch. Pracovisko číslo šesť má na starosti riadenie toku materiálu, zariadení a ľudí, bezpečnosť s využitím RTLS. RTLS systém má za úlohu tzv. „trekovanie“, čo znamená sledovanie toku materiálu, pracovníkov a zariadení výrobného objektu, v danom prípade pracoviska TestBed. Posledným pracoviskom je pracovisko s číslom sedem, ktorý sa skladá zo štyroch buniek, určených na aplikáciu konceptu digitálneho dvojčaťa. Prebiehajú tam procesy ako návrh, overenie a optimalizácia nových procesov, pracovísk, liniek a prevádzok pre výrobu a logistiku. Návrh, overenie a optimalizácia výrobných logistických tokov materiálu, trás, využitia techniky, pracovnej sily, balných množstiev. Taktiež tam prebieha tvorba konceptu, spolupráca pri vývoji, konštrukcii a odladenie výrobných liniek a automatizovaných zariadení do prevádzky vo virtuálnom prostredí. Vykonáva sa tam aj overenie a optimalizácia riešení navrhnutých treťou stranou, montážnych procesov, či výrobného traktu.

Poďakovanie
Tento článok bol vytvorený realizáciou grantových projektov VEGA 1/0438/20 Interakcia digitálnych technológií za účelom podpory softvérovej a hardvérovej komunikácie pokročilej platformy systému výroby, KEGA 001TUKE-4/2020 Modernizácia výučby priemyselného inžinierstva za účelom rozvoja zručností existujúceho vzdelávacieho programu v špecializovanom laboratóriu, APVV-17-0258 Aplikácia prvkov digitálneho inžinierstva pri inovácii a optimalizácii produkčných tokov a APVV-19-0418 Inteligentné riešenia pre zvýšenie inovačnej schopnosti podnikov v procese ich transformácie na inteligentné podniky.

Záver
Digitalizácia sa stala neoddeliteľnou súčasťou dnešného sveta a sme priamymi svedkami toho, ako odvetvie priemyselného inžinierstva nadobúda novú podobu. Vďaka digitalizácii vznikla nová škála produktov a služieb, ktoré uľahčujú prácu priemyselným spoločnostiam.
Hlavným cieľom tohto príspevku bolo vytvorenie vizualizácie konceptu TestBed v počítačovom programe pre 3D modelovanie SketchUp, kde sme v krátkosti predstavili prostredie. Dnešný trh ponúka veľké množstvo individuálneho softvéru, ktorý je navrhnutý na vytváranie podobných vizualizačných modelov, ale jedným z dôvodov, prečo sme si vybrali tento softvér, je jeho jednoduchá a intuitívna obsluha a skutočnosť, že nie je potrebné platiť za licenciu na vzdelávanie.
Je dôležité spomenúť, že koncept vizualizácie neoddeliteľne zahŕňa spojenie s virtuálnou a zmiešanou realitou, ktorá dnes zažíva rozmach nielen v priemysle, ale v rôznych oblastiach života od medicíny po herný priemysel. Existuje veľký predpoklad, že tento trend nebude klesať.

Referencie

[1] ROSKES, Bonnie a Bob DEWITT. The SketchUp book: for Version 5. 3nd ed.: 2005, West Caldwell, NJ: Conceptual Product Development.
[2] SketchUp blog [online]. Dostupné na internete: <https://blog.sketchup.com/products >
[3] EDULEARN [online]. Dostupné na internete: < https://www.edulearn.com/article/what_is_revit_architecture.html >.
[4] GRZNAR, P., GREGOR, M., MOZOL, S., KRAJCOVIC, M., DULINA, L., GASO, M., MAJOR, M.: A System to Determine the Optimal Work-in-Progress Inventory Stored in Interoperation Manufacturing Buffers, Sustainability, vol. 11, no. 14, 1-36, doi: 10.3390/su11143949, 2019.
[5] VINESH, R.; KIRAN, F.: Reverse Engineering – An Industrial Perspective, Springer Science, London, 2008, ISBN 978-1-84628-855-5.
[6] EDL, M., LERHER, T., ROSI, B. (2013), „Energy efficiency model for the mini-load automated storage and retrieval systems“. International Journal of Advanced Manufacturing Technology, , č. 2013, s. 1-19. ISSN: 0268-3768.
[7] STRAKA, M., LENORT, R., KHOURI, S., FELIKS, J.: (2018) „Design of large-scale logistics systems using computer simulation hierarchic structure“, International Journal of Simulation Modelling, Vol. 17, No. 1, pp. 105-118.

Kontakntá adresa

Ing. Marek Mizerák.
Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Park Komenskeho 9, 042 00 Kosice, Slovakia
e-mail: marek.mizerak@tuke.sk

Review process

Single-blind peer review process.