

# INTERDISCIPLINARY DESCRIPTION OF COMPLEX SYSTEMS

## Scientific Journal

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# ENGINEERING JOB SKILLS IN CROATIAN ECONOMY: EMPLOYERS' PERSPECTIVE

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## ABSTRACT

Different actors, or stakeholders, are interested and want to participate in discussions and interventions related to the topic of skills as an important outcome of engineering education. In the Croatian context, the entire process is still predominantly internally driven and determined by academic evaluations while the involvement of the alumni and employers as external stakeholders is sporadic and under researched. Since Croatian employers are not sufficiently familiar with the levels and structures of reformed study programs, the main objective of this research was to assess to what extent the current and largely accepted set of engineering skills fit their expectations.

By reviewing available literature, 36 key skills were identified and used in a questionnaire administrated to Croatian employers, resulting in 418 completed and usable responses. Results show that employers find every assessed skill as somewhat/extremely valuable. However, it is found that employers most valued skills related to the wider set of transferable skills with somewhat greater emphases on skills that reflect professionalism and work ethic. In general, it turned out that employers approach transferable skills in terms of their functionality. Mean comparison within subgroups has shown statistically significant differences with regard to respondent's gender. In general, women fit the theorized dimensions more than their male counterparts, perhaps indicating that they understand all skills, and transferable skills in particular, more holistically than men.

Finally, in order to understand the underlying structure of the explored items, exploratory factor analysis was employed, resulting in 8 clear dimensions suggesting engineering "employability skills" in the Croatian context.

## KEYWORDS

engineering, skills, learning outcomes, employers

## CLASSIFICATION

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## INTRODUCTION

To say that recent developments in work arrangements and a rapid growth in technological innovation constantly challenge engineering education to transform itself and to meet demands of engineering practice seems urgent in an age of globalization, precarious, flexible work and ubiquity of digital technology. At the same time, it seems like a long and thoroughly discussed theme in the literature concerned with relations between engineering education and practice. Basically, at least from the middle of the twentieth century, literature on engineering education addresses different aspects of tensions between engineering education and engineering practice [1-2]. In general, until the 1980s, this discussion was framed by Fordist models of capitalist accumulation and reproduction with images of engineers as professionals who were supposed to find their area of activity predominantly in industrial settings, and to be equipped with knowledge of engineering science with the addition of some functional information stemming from the field of organizational studies like management, industrial sociology and industrial psychology.

However, since the 1980s, the neoliberal phase in socio-economic developments of industrial capitalist societies, coupled with the rise of information technology and globalisation, influenced the landscape of engineering activities, changing not only the scope of engineering practice beyond industrial settings but also prevalent images of what engineers are as a profession, what they precisely do while working, what their working material and human environment would look like in times to come.

As indicated by several authors [3-4], engineering practice in the manufacturing sector has gone beyond strictly technical engineering roles, while simultaneously expanding towards activities in the service and public sectors. Already in the 1990s, Barley and Orr [5] pointed to the analytical difficulties that arose from blurring boundaries between technical and, for example, accounting work, as represented in the official occupational classifications. While they concentrated primarily on technicians, Barley and Orr offered a developmental contour of technization of work at the societal level: “By technization, we mean to characterize the emergence of work, which is comparatively complex, analytic, and even abstract, because it makes use of tools that generate symbolic representations of physical phenomena and that often mediate between workers and the objects of their work” [5; p.5]. In regard to the expansion of possibilities for engineers to be employed outside the manufacturing settings, the National Academy of Engineering (NAE) clearly indicated the need for an engineering education oriented towards a wide range of career opportunities that include non-engineering jobs [6]. As an example of non-traditional engineering employment area, Beder singled out financial firms where engineers’ problem solving, mathematical and computer skills in the context of financial transactions becoming more complex were recognized as desired [3]. More recently, Krawczyk and Murphy pointed out a similar perspective: “There is no single archetypal engineer or pattern that universally describes what engineers are in the world of 2011. Descriptions of engineers tend to focus on what engineers do rather than on the intrinsic characteristics of what makes someone an engineer. Engineers practice in many diverse disciplines and perform many diverse roles, even within those disciplines. There are also many people who have been educated as engineers but no longer work in engineering roles” [4; p.110].

All these authors, as well as many others [7-10], have considered those changes in terms of skills and competencies engineers need in contemporary circumstances. Sometimes the skills are covered under the umbrella of “employability” [11]; sometimes they are covered through the number of general descriptions that usually include knowledge, intellectual skills, practical skills and transferable skills [4]. In any case, some kind of a common viewpoint and

frame are concisely offered through accreditation agencies' recommendations, which generalize the issues of engineering skills and competencies in terms of learning outcomes – a concept that recently became both a dominant and “the principal instrument to describe competency” [12; p.9].

In the process of reforming higher education in Croatia in accordance with the Bologna declaration, the aforementioned recommendations represent an important frame of reference for numerous engineering higher education institutions. Therefore, learning outcomes have become a usual reference for knowledge, competencies and skills in the engineering field, although occasionally constructed in a manner that reflect long established and deeply internalized practices of “problem solving” among Croatian engineers [13] rather than a systematic effort of national engineering associations to foresee the meaning of engineering in the long-term perspective of Croatian social and economic development. This means that the overall engineering field is fragmented with some higher education institutions trying to officially acquire international accreditations, while others strive to follow these recommendations in an informal way, ingeniously phrasing learning outcomes to fit their own needs. The entire process is still predominantly internally driven and determined by academic evaluations, while the involvement of alumni and employers as external stakeholders is sporadic and under researched. For example, it has been already pointed out that Croatian employers are not sufficiently familiar with the levels and structures of reformed study programs [14]. An effort to involve employers was made in the creation of the catalogue of knowledge, skills and competencies for Croatian mechanical engineering study programs [15]. However, results seem to be unreliable since the research procedure has not been presented in sufficient detail, and the sample of employers (46) was relatively small to allow for wider generalisations.

If the learning outcomes approach in the current process of harmonization of Croatian and European higher education system does not cover suggestions from different stakeholders in education, then our primary research objective will be to assess the extent to which the prevailing learning outcomes in engineering study programs in Croatia meet the expectations of employers. In addition, since the learning outcomes approach as a synthesizing instrument for estimating engineering skills and competencies in Croatia is still fragmented and relatively diverse, we have also tried to define the key components of skills and competencies as elaborated in the literature we have found relevant for our study and to estimate to what extent employers consider them important. Finally, the present research examines whether it is possible to determine differences in employers' ratings of skills and competencies by a number of independent variables, such as the employers' field of activity, enterprise size, private or public ownership, engineering professions they employ and by gender of respondents as the single socio-demographic feature selected for the study.

## **CONCEPTUAL BACKGROUND**

Generally, the skill-based approach in engineering has corresponded to a wider educational turn since the 1980s and to educational policy efforts in European countries in order to promote education as the most important generator of economic growth [16]. Still, it is evident that skills and competencies have various definitions, as the perspectives of key stakeholders in academic engineering education (employers, academic institutions, students, engineering associations, and alumni) often express different positions, interests and problems [12]. This process has resulted in formulations of qualifications frameworks as conceptual backgrounds of arising European and national educational architectures oriented toward learning outcomes and skills as the main indicators of quality of education. As fundamentally social and dubious in its character, the very concept of knowledge society in which education crucially affects economic development altogether with the process of

developing a framework of qualifications has been widely questioned and criticised as a policy device for wider marketization of education and its adaptation to the needs of profit-oriented external stakeholders, i.e., employers [12, 17-20]. However, almost none of the critics dispute neither the issue of skills and learning outcomes nor the research of employers' perspective on (engineering) education and preferable skills formation as the relevant subject.

Conceptualizations of engineering skills and competencies are usually grouped around several general features. Principally, these features are derived from a list of skills formulated by various organisations, national bodies or quality assurance agencies around the world [11, 21], and are explicitly or implicitly taken into account and thoroughly discussed in the corresponding literature. For example, the Accreditation Board for Engineering and Technology (ABET) EC2000's Criterion 3 [22] specifies 11 student learning skills (or, more precisely, learning outcomes), representing a frame of reference for engineering studies worldwide, including some Croatian engineering faculties. In the context of European engineering higher education, these skills are elaborated by quality assurance institutions, among which some, like *Akkreditierungsagentur für Studiengänge der Ingenieurwissenschaften, der Informatik, der Naturwissenschaften und der Mathematik* (ASIIN), accredit and advise some Croatian and other higher education institutions throughout the whole of Europe. In the case of ABET, proposed outcomes are provided for undergraduate engineering programs, while in the case of the ASIIN, these outcomes are formulated according to research and practice-oriented programs as at least two typical general profiles of engineering studies. Additionally, ASIIN differentiates ideal learning outcomes for Bachelor's and Master's degree as an orientation guideline. Thus, requirements for Master's degree programmes are conceived as a continuation of an initial university degree leading "to the acquisition of advanced analytic-methodical and technical competencies" [23; p.5].

In regard to specific learning outcomes, there is significant similarity among aforementioned and other organisations, national bodies or quality assurance agencies [11, 21]. The same goes for general features into which these outcomes are synthesized. By establishing the broadest perspective possible with regard to the diverse branches of engineering, the National Academy of Engineering (NAE) has considered skills that, in terms of attributes, engineers will need in 2020.

NAE predicted analytical skills as desirable, confirming their lasting value. The next predicted feature has pointed to practical ingenuity as a set of skills that represent the ability to define problems and to find solutions through the use of science. The next set of skills are covered by the term creativity to emphasize the importance of "invention, innovation, thinking outside the box, (and) art" in dealing with the growing "complexity and diversity of the technologies of the 21st century" [6; p.55]. The last two set of skills have involved professionalism and leadership as a way to sum up the so-called transferable skills. These involve abilities to communicate well; to express leadership skills based on the understanding of corresponding principles since the possibilities for engineers to be employed outside manufacturing settings will grow; to act according to high ethical standards; to understand the contemporary social context, which requires flexibility, resilience or agility; and finally to be life-long learners.

The NAE attributes are scenario-based, for they were thought to differentiate several possible upcoming trends in the future. A corresponding scenario-based approach is used by Krawczyk and Murphy [4], who surmised three scenario options. The first involves the possibility of continuation of existing socio-economic order, the second considered radical transformation towards just, peaceful and sustainable world, and the third referred to a kind of possible social, cultural, political and economic regression with the dramatic rise of environmental problems, social injustice, the establishment of firm hierarchical structures, etc. They suggested a related set of composite skills: knowledge skills, intellectual skills, practical skills and general

transferable skills. Here, the knowledge skills correspond to NAE's analytical skills and refer to knowledge and understanding of the essentials of engineering science. Intellectual skills correspond to NAE's term, creativity, while practical skills correspond to practical ingenuity as proposed by NAE. Finally, general transferable skills refer to professionalism and leadership as described in NAE publication. As regards a different certainty of scenarios, Krawczyk and Murphy have suggested that all the same skills would be needed; the only difference refers to "problems and projects these skills will be applied against" [4; p.118].

Both approaches use ABET recommendations as a basic conceptual framework. Considering its wide utilisation in creation of instruments for measuring ABET's 11 learning skills, Strauss and Terenzini pointed out that flexibility of interpretation as its main advantage could also be the source of ambiguities "in defining and measuring the skills that students must demonstrate if a program is to meet the intent of the criteria" [24; p.10.927.2]. Their effort to develop psychometrically sound instrument for assessing different stakeholders' viewpoints on engineering higher education learning outcomes has resulted in nine-factor solution representing the main corresponding engineering skills as follows: design and analytical skills, societal and global issues, codes and ethics, experimental skills, communication skills, applying engineering skills, group skills, life-long learning, and applying basic skills.

In other related literature, the skills employers perceived as important are also considered in terms of learning outcomes and personal attributes of graduated engineers. In most of them, it is possible to discern explicitly or implicitly stated that engineering higher education has to be the driving force in improving the competitiveness of national economies. In a way, for a number of these research reports, Drucker's critical observations of the failures of American educational institutions from the 1990s to prepare the students for the world of business can be seen as a common conceptual background [25]. Research reports refer to studies around the world – from the USA, Great Britain to South-East Asia and Australia.

In the Australian context, Hagan has found that 40 % of employers were not satisfied with the level of ITC students' mastery of some generic skills, mostly their business management skills and communication skills [26]. Marques offered systematic literature review on engineering skills that British employers perceive as important in contemporary flexible companies that strive to cope with constant and rapid changes [11]. In a similar way, Prados, Peterson and Lattuca explain the reasons for the key changes that have taken place in the process of revision of ABET recommendations, which put in the foreground the ever-changing needs of engineering practice [27].

Some corresponding research have been conducted in fast-growing economies like India, Malaysia, Sri Lanka, as well as have been concerned with the wider regional scope. As a background assumption, there is, again, the importance of engineers for national economic, technological and infrastructural development in times of constant changes, which force these nations to deal with new challenges [21, 28, 29]. For example, Blom and Saeki have seen the research of employers' perception of important engineering skills as a necessary contribution to balancing educational system within the Indian economy, which during their research was growing over by 8 % annually, including the year of the financial crisis in 2009 [30]. Blom and Saeki stated that the growing need for engineers in relation to the increase in educational institutions resulted in the decrease of the quality of skills employers needed.

Finally, Zaharim et al. have proposed a model of engineering employability skills that intend to provide a framework for Malaysian engineering programmes. Relying on existing researches, different national and international accrediting bodies and frameworks, the authors have also comparatively revised engineering skills and attributes required for engineering graduates worldwide [21].

In sum, all of the aforementioned studies converge toward a relatively close set of engineering skills with more or less attention given to ABET EC2000’s Criterion 3 as an important reference. The same goes for the present study – three main sources we have referred to in more detail in the first part of this chapter, namely, NAE report, Krawczyk and Murphy’s study and Strauss and Terenzini’s nine set skills solution, are altogether derived from or based on ABET’s list. Therefore, their sets of skills converge as shown in Table 1.

**Table 1.** Engineering skills as defined in the selected research.

<b>NAE</b>	<b>Krawczyk and Murphy</b>	<b>Strauss and Terenzini</b>
Analytical skills	Knowledge skills	Applying Basic skills
Ingenuity	Practical skills	Applying Engineering skills Experimental skills
Creativity	Intellectual skills	Design and analytical skills
Professionalism Leadership	General transferable skills	Societal and global issues Codes and ethics Communication skills Group skills Lifelong learning

## METHODOLOGY

Working under the assumption that employers aren’t keen on participating in studies, in order to secure enough responses, an oversampling of engineer employers has been made using both the register of Croatian’s Chamber of Commerce [31] and the archive of the Faculty of Mechanical Engineering and Naval Architecture (FAMENA) [32] “job openings and scholarships” column. As the Chamber of Commerce’s archive lists every legal entity in Croatia, a few restrictions had to be implemented in order to reach a, not only sufficient, but also efficient sample.

In order to enter the sample, companies had to be both active and must have delivered the financial report for the year<sup>1</sup> 2015. After this first filter, companies were sorted in descending order to accommodate their total income and number of employees. While their total income was not additionally categorized, companies have been categorized by their number of employees in big (more than 250), medium (50 to 249), small (10 to 49) and micro (1 to 9) entities, with each category yielding no more than 250 subjects per category. These filters have been implemented for each category of the National Classification of Occupation as listed in the People’s Newspaper<sup>2</sup> [33], yielding a total of 15 785 contacts. After retaining only unique values (one e-mail per company), the total number of contacts dropped to 7 586. Browsing the archives of FAMENA’s aforementioned column back to the beginning of 2012 yielded an additional 27 unique employers.

University of Zagreb’s University Computing Centre’s (SRCE) Lime Survey service was used to contact all the employers, additionally asking them to snowball the questionnaire to other engineers’ employers, which resulted in a total of 8 878 contacts. As expected, the response rate was low, with only 478 participants filling out the questionnaire. After eliminating participants whose responses were incomplete, or who said they did not employ engineers at all, the final number of usable responses dropped to 418.

## QUESTIONNAIRE CONSTRUCTION

In constructing the questionnaire, this study tried to cover a widespread theoretical and empirical background of engineer employability research, drawing from a wide body of articles as well as curricula mentioned in the conceptual background [11, 21-23, 24, 28-30, 34-38]. Trying to utilize previous findings as best as possible, all researched and/or recommended skills were taken into account, resulting in 107 unique entries. In order to make sense of such a large number, content analysis was employed. Combining or deleting variables that resemble each other to some degree, consulting mainly the works of Strauss and Terenzini and that of Zaharim et al., while adding a number of variables specific to FAMENA's curriculum, led to a total of 36 skills, grouped in 10 categories to be explored.

The final was a two-part questionnaire, which consisted of general information about the respondent's company and 36 items comprising skills employers could find valuable in engineers, rated on a 5-point scale, ranging from "1 – Not at all important" to "5 – Extremely important". In order to avoid fence-sitting and add clarity to the results, the value of 3 – "could not estimate" – was subsequently eliminated from the analysis. Based on the literature overview as well as their conceptual meaning, the 36 items were divided into 9 + 13 dimensions<sup>3</sup>, labelled as Communication skills (3 items), Lifelong learning (3 items), Teamwork (5 items), Experimentation (2 items), Ethics and responsibility (3 items), Professionalism (5 items), Project management (3 items), Specific skills (3 items), and Other (6 items). Most of the mentioned dimensions were retained via dimension reduction procedures.

## FINDINGS

### DATA ANALYSIS

SPSS 22 software was used to statistically analyse the data. Mean differences (one sample *t*-test, *t*-tests of independent samples, and ANOVA) were tested at  $p < 0,05$  significance, with ANOVA employing Bonferroni's test when equal variances were assumed, and Tamhane's T2 test when equal variances were not assumed. Dimension reduction was conducted via exploratory factor analysis(EFA), extracting dimensions based on eigenvalue greater than 1, employing direct oblimin rotation (presuming dimensions were correlated), and excluding missing values by a pair wise method to retain the most number of answers. In order to test scale construction, Cronbach's alpha method was employed.

### SAMPLE'S PROFILE

As mentioned in the previous section, a total of 418 respondents/companies participated in the questionnaire, mainly coming from the *private sector* (360), with 56 *government-linked* companies and 2 from NGOs. Based on their size, 88 companies were *micro*, 169 *small*, 104 *medium*, and 57 *big*, with the majority of them coming from economic branches such as *manufacturing* (78), *construction* (70), *ICT* (46), and *professional, scientific, and technical activities* (33). The majority of these organizations employed engineers as *in-house professionals* (329), 27 *outsourced* them, while 62 of them used a combination of the two. The most sought-after professions were *mechanical engineers* (197), *computer engineers* (63), *construction engineers* (46), and *electrical engineers* (30).

In regard to their position within the organization, most of the respondents were *directors, owners or members of the supervisory board* (223), with the rest being *HR managers or employees* (68), *managers of other departments* (94) or *other* (33); while in regard to their gender, 279 respondents were *male* and 127 respondents were *female*.

Additionally, in order to emphasize the importance of gathered responses, respondents who did not partake in the process of employing engineers in the last five years (69) were excluded from further analysis, resulting in a working sample of 349.

## **EMPLOYERS' EVALUATION OF EMPLOYABILITY SKILLS**

As aforementioned, even though the scale was originally 5 points, after eliminating the middle value, 4 points were retained, namely: "1 – not at all important", "2 – somewhat unimportant", "3 – somewhat important", and "4 – extremely important". Of the 36 items, only one came close to being rated as somewhat unimportant (General knowledge about national and international events – Mean 2.48), while 17 were rated as extremely important, and 18 as somewhat important (Table 2)<sup>4</sup>.

Apart from the mean values being extremely positively skewed, what is immediately evident about the data is the overall low standard deviation of scores. Every item has a standard deviation lower than 1, and the 9 highest items sorted by means have an SD lower than 0,5, indicating not only that employers want engineers who "have it all", but that all these skills are treated as equally "extremely important" regardless of the economic branch the organization conducts its business in, its size, the specialists it employs or its governmental/private/NGO ownership. Although all skills are seen as valuable, some domains do seem to be more valuable than others.

*Professionalism*, which is portrayed as the ability to work under pressure and follow directions while staying motivated, conscientious, and respecting deadlines is found extremely important by employers.

Not only do employers want professional employees; they want them to be extremely good at *problem-solving* as well, which comes as no surprise, with engineers enjoying a reputation of fixers and tinkers. Such problem-solving skills are theoretically expected to be portrayed by items that measure the importance of the ability to identify and define problems independently, design practical solutions to fix them as well as being capable of approaching the problem from different angles.

In contrast to the extremely favourable attitudes towards problem solving, employers seem to miss its connection with skills linked to *designing experiments* and analysing and interpreting their data (both rated statistically significantly lower than all problem-solving items), or even to the connection of gaining a specialization in a specific field (significantly lower than all problem solving items), as they would rather employ engineers who are "jacks-of-all-trades" than specialists in their specific fields, somehow hinting at their wants of having innovative designs and technologies without wasting time and money on R&D. That cream-of-the-crop approach seems to lead employers' thinking in other dimensions, too.

Although *teamwork* is found extremely valuable, employers favour an ability to work in interdisciplinary teams, as well as the ability to come to optimal solutions in them and understanding one's role statistically higher more than emotion management, empathy and abilities to lead teams. Likewise, *project management* skills are rated only somewhat important with the highest ranked being the ability to write technical documentation, while abilities to think, plan and lead strategically, as well as design quality management systems are rated statistically significantly lower and seem to be less of a concern.

*Communication skills* are regarded as extremely favourable in terms of abilities to express oneself clearly and to convey engineering ideas and solution to a non-professional public, but the ability to negotiate with others (which, apart from clients, includes employers too), although still positive, is regarded as a significantly less favourable trait.

Two of the three items measuring *ethics and responsibility* are ranked relatively low, with one exception being the ability to follow and implement rules of the profession (rated significantly higher than the other two items from this domain), perhaps because of it being more linked to the concept of professionalism, while the other two might be either considered important or are just socially acceptable responses.

*Specific skills* are rated moderately high, with the ability to use and implement specific tools, skills and techniques seen as an extremely important skill, while the ability to use advanced computer software (perhaps, linked with the experimenting domain) and the ability to recognize interactions between elements in technical systems (perhaps, linked with the project leading domain) are rated significantly lower.

Finally, the items defining the *Other* domain sank to the bottom of the importance scale, with the exception being the ability to understand a foreign professional language and, somewhat, having had a practical experience during formal education. Apart from the ability to understand advanced mathematics, understanding contemporary political, economic and ecologic problems, having a general knowledge of current national and international events, as well as having an understanding of the global repercussions and significance of engineering solutions, seem to be of little importance to employers. Such low scores, perhaps, accentuate the wants of employers to employ engineers as “doers” and not “thinkers” and shed some additional doubt on the social acceptability quality of ethics and responsibility answers.

In order to further explore possible differences in skill appreciation between employers, *t*-test and ANOVA analyses were conducted based on independent variables such as *respondent's gender*, their *positions* within the organizations, the *specialists* they employ, as well as the *economic field*, and their total *number of employees*.

While the total number of employees, the economic field of the organization, as well as respondents' position within them yielded particularly no interesting findings, with just a few statistically significant differences, respondents do seem to value different skills very differently based on their gender and slightly differently based on the organizations' ownership.

Generally speaking, women tend to value all measured skills more than men, with a mean of 3,5 compared to the 3,3 of their counterparts, and with 26 out of 36 skills being statistically significantly higher, which makes them somewhat harder to impress during the hiring process. What is especially interesting would be their focus on some of the theorized dimensions, where women value all of the items, including the *Communication skills*, *Experimentation*, *Ethics*, and *Project management* dimensions, except *Professionalism* and *Problem solving*<sup>5</sup>.

Although just a few skills were rated significantly different when compared to the available ownership categories, their domain setup showed an interesting and, perhaps, expected difference between respondents from government-owned and private-owned organizations, with the former valuing items comprising *The Ethics and responsibility* domains significantly higher than the latter. Although not all the items measuring the aforementioned domain were statistically different,<sup>6</sup> there seem to be a notable difference in value (if not in practice) between the two types of ownership, especially if we note that there's a statistical difference in the item “Conscientiousness and ability to implement rules of the profession”, too.

**Table 2.** Mean and standard deviation values of items operationalizing engineer skills (continued on p.11).

<b>Item</b>	<b>N</b>	<b>Mean</b>	<b>SD</b>	<b>Theorized Dimension</b>
Professional and conscientious approach to work tasks	317	3,9	0,349	Professionalism
Willingness for lifelong learning of engineering knowledge, skills and techniques	326	3,8	0,465	Lifelong learning
Motivated approach to work tasks	321	3,8	0,440	Professionalism
Conscientiousness and ability to implement rules of the profession	324	3,7	0,443	Ethics and responsibility
Ability to respect deadlines	318	3,7	0,436	Professionalism
Ability to come to an optimal solution while working with others (engineers and non-engineers alike)	320	3,7	0,503	Teamwork
Ability to independently identify and define problems that need solving	322	3,7	0,499	Problem solving
Understanding and respecting one's and others' role in the teamwork	327	3,7	0,493	Teamwork
Ability to find different solutions to existing problems	321	3,7	0,484	Problem solving
Concise and clear communication of ideas to non-engineers (public, clients...)	332	3,6	0,546	Communication skills
An active interest in engineering evolution of technology, knowledge, skills and techniques	322	3,6	0,531	Lifelong learning
Design solution to meet desired needs	322	3,6	0,567	Problem solving
Ability to communicate and express oneself clearly	331	3,6	0,528	Communication skills
Ability to work under pressure (deadlines, downsizings, demanding clients...)	319	3,6	0,583	Professionalism
Ability to choose and use specific engineering tools, skills and techniques	314	3,6	0,570	Specific skills
Ability to work well in interdisciplinary teams	327	3,5	0,610	Teamwork
Ability to follow directions when working on tasks	320	3,5	0,571	Professionalism
Understanding a foreign professional language	312	3,4	0,661	Other
Ability to lead teams	324	3,4	0,641	Teamwork

**Table 2.** Mean and standard deviation values of items operationalizing engineer skills (continuation from p.10).

<b>Item</b>	<b>N</b>	<b>Mean</b>	<b>SD</b>	<b>Theorized Dimension</b>
Ability to write technical documentation	315	3,4	0,681	Project management
Ability to use advanced computer software	316	3,4	0,661	Specific skills
Ability to negotiate with clients and employers	326	3,4	0,729	Communication skills
Making ethical standards a priority when working on tasks	320	3,3	0,677	Ethics and responsibility
Ability to manage one's and recognizing others' emotions	326	3,3	0,632	Teamwork
Taking into account societal and environmental repercussions when designing engineering solutions	319	3,3	0,647	Ethics and responsibility
Specialization in an engineering field	321	3,3	0,688	Lifelong learning
Ability to think, plan and lead projects strategically	317	3,2	0,661	Project management
Practical experience during formal education	314	3,2	0,783	Other
Ability to recognize interactions between elements in technical systems and processes	311	3,2	0,692	Specific skills
Ability to design and lead experiments in order to test new technical solutions	323	3,1	0,789	Experimentation
Ability to design processes of quality management	314	3,1	0,699	Project management
Ability to analyse and interpret experiment results	323	2,9	0,831	Experimentation
Understanding the global repercussions of engineering solutions	305	2,7	0,780	Other
Advanced understanding of mathematics	305	2,7	0,784	Other
Understanding contemporary (economic, ecological, political...) problems	311	2,6	0,759	Other
General knowledge of national and international events	306	2,5	0,842	Other

## DIMENSION REDUCTION

In order to shed some light on the underlying dimensional construct of the questionnaire, an explorative factor analysis was conducted, as explained in the *data analysis* section. After purifying the initial solution and removing items that either saturated too many dimensions, had low Cronbach values or simply didn't make sense considering the solution, 29 items were retained. The final solution resulted in an 8-factor structure, explaining 62 % of the overall variance among the 29 items (Table 3).

All retained items loaded above 0,48 on a single factor and all of the factor scales scored above 0,6 except the domain of communication skills. The final factor solution shows that most of the theorized domains were retained, with the exception of the domains of *Problem-solving*, *Project management*, and *Specific skills*, whose items ended up separating and saturating other factors. Specific skills items, as well as project management items, combined and formed the principal component of this structure, named *Technical and managerial skills*. And while two out of three items from the problem-solving theorized dimension were deleted, one was retained in the *experimentation* domain.

As can be seen in Table 3, the principal component of the factor solution can be traced to abilities that make up day-to-day activities in most of the engineering positions, where employees are tasked with a plethora of jobs, ranging from writing technical documentation to applying specific informational and engineering knowledge to planning, and leading various projects.

Although its items ranked fairly low in terms of importance, the next retained dimension, *Globality of engineering* grouped three items from *Other* dimension, and accounted for 7,6 % of the total variance explained, showing that, although employers do not find these skills particularly important, they do tend to think about them as a part of the engineering skills toolkit.

Unsurprisingly, the two items comprising the theorized *Communication skills* saturated the first confirmed factor through dimension reduction and explained 6,4 % of the total variance. Although its Cronbach alpha does verge on the unacceptance edge, it's fairly clear composition and fairly high percentage of variance explained could mean the scale would just need a few more related items in the questionnaire to achieve far higher values.

The *Teamwork* dimension is also one of the retained theorized dimensions, accounting for 5,4 % of the total variance explained. Although grouping 5 items, items measuring abilities to lead teams, as well as a variant of emotional intelligence, saturate the factor less than items measuring abilities more overtly linked to "productive" teamwork, as if employers did understand their role in teamwork, but, perhaps, underestimated their value in making a team function properly.

*Lifelong learning* retained all the theorized items, accounting for 5 % of the variance and, while employers seem to value highly a willingness to keep expanding one's knowledge, specializations in specific fields saturate this factor far less.

*Professionalism* accounted for 4 % of the total variance explained, grouping 4 theorized items, showing that not only do employers value those skills highly (as shown in Table 3) but they find them connected, expecting employees to be able to respect deadlines and work under pressure while being able to keep themselves motivated and in line with given directions.

*Ethics and responsibility* also retained its initial items, accounting for 4 % of the total variance, showing that employers find both "micro-ethics" (such as putting ethical standards at the foremost place when working, and being conscientious by implementing professional rules) and "macro-ethics" (such as taking into account the societal and environmental repercussions of engineering) as part of an ethical approach in engineering work.

**Table 3.** Factor structure underlying items operationalizing engineer skills.

Highest Loading Items	Factor Loading	Scale Alpha	Variance explained
<b>1. Technical and managerial skills</b>		0,8	26,0 %
Ability to write technical documentation	0,718		
Ability to design processes of quality management	0,663		
Ability to choose and use specific engineering tools, skills, techniques	0,659		
Ability to use advanced computer software	0,634		
Ability to think, plan and lead projects strategically	0,630		
Ability to recognize interactions between elements in technical systems and processes	0,616		
<b>2. Globality of engineering</b>		0,86	7,6 %
Understanding contemporary (economic, ecological, ...) problems	-0,851		
General knowledge about national and international events	-0,834		
Understanding the global repercussions of engineering solutions	-0,806		
<b>3. Communication skills</b>		0,56	6,4 %
Concise and clear communication of ideas to non-engineers (public, clients...)	0,822		
Ability to communicate and express oneself clearly	0,806		
<b>4. Teamwork</b>		0,68	5,4 %
Understanding and respecting one's and others' role in teamwork	0,723		
Ability to work well in interdisciplinary teams	0,688		
Ability to come to an optimal solution while working with others (engineers and non-engineers alike)	0,597		
Ability to lead teams	0,570		
Ability to manage one's and recognize others' emotions	0,523		
<b>5. Lifelong learning</b>		0,63	4,9 %
Willingness for lifelong learning of engineering knowledge, skills and techniques	-0,781		
An active interest in engineering evolution of technology, knowledge, skills and techniques	-0,754		
Specialization in an engineering field	-0,550		
<b>6. Professionalism</b>		0,71	4,1 %
Ability to respect deadlines	-0,784		
Ability to follow directions when working on tasks	-0,777		
Motivated approach to work tasks	-0,705		
Ability to work under pressure (deadlines, downsizings, demanding clients...)	-0,604		
<b>7. Ethics and responsibility</b>		0,66	4,0 %
Putting ethical standards at the foremost place when working on tasks	-0,757		
Conscientiousness and ability to implement rules of the profession	-0,744		
Taking into account societal and environmental repercussions when designing engineering solutions	-0,697		
<b>8. Experimenting</b>		0,73	3,8 %
Ability to design and lead experiments in order to test new technical solutions	0,883		
Ability to analyse and interpret experiment results	0,820		
Design solution to meet desired needs	0,475		
			62,1 %

Finally, although ranked fairly low on importance, *Experimenting* retained its two theorized items, and grouped one of the mainly deleted *problem-solving* domain. Accounting for 3,8 % of the total variance, this dimension grouped abilities to design and lead experiments as well as analyse and interpret their data. But as mentioned in the previous section, employers do not seem to be all that keen on “wasting time” experimenting, unless it leads to new and practical discoveries, as shown by the third item comprising this domain.

As the component correlation matrix ranged from low (0,03) to moderate (0,3), a second-order analysis was implemented in order to check whether it is possible to treat the final version of the instrument as a unidimensional scale with a Cronbach alpha score of 0,9. Second-order factor analysis yielded 3 factors, while a third-order factor analysis led to only one factor. Such results seem to dismiss the idea of unidimensionality of the scale, so Cronbach alpha scores should be measured at subscale/domain levels.

Finally, it should be noted that a shorter version of this scale, containing 24 items throughout 8 dimensions and explaining 66 % of the total variance can be constructed. But since this is the first kind of explorative factor analysis on a Croatian sample, it was thought best to retain as many items as possible in order to facilitate possible future research.

## DISCUSSION

Although most of the items used to estimate skills and learning outcomes of Croatian engineering study programs are relatively highly valued by Croatian employers, some differences in their ratings could be discussed in more detail.

Starting with some of the unexpected results, a relatively lesser importance given to skills of experimentation and the practical experience students acquire during their education seem to be contrary to the image of inventors and tinkerers engineers maintain in society, while a common student’s wish to gain more practical experience seems not to be reflected in the needs of future employers. Theory-practice issues have already been discussed in terms of tensions inherent in engineering education, with a possible consequence in the distancing of engineers working in the academic sector from the practice of everyday engineering [39]. As Jamison and Heymann have pointed out “... distance mattered all the more, because teachers and professors now became removed from their original professional location, the engineer in industrial practice, while they successfully created a new profession, the engineering professor, with its own culture and set of norms and values” [39; p.192]. On the other hand, increased educational ascent on experimentation and laboratory work could be considered a visible consequence of the self-imposed direction toward greater scientification, which is believed to be an important vehicle in the recognition of engineers and engineering in general in the society [1-3]. However, based on the results of this study, it seems that the considerable educational efforts towards implementing practical and laboratory work in curricula do not clearly meet Croatian employers’ expectations. As related research on a Croatian sample is scarce to non-existent, interpreting results is impossible since theoretical possibilities range from those of Croatian employers considering the issue of practical experience being a regular part of apprenticeship and organisational socialization, to the lack of interest in research, development, and innovation by the Croatian business sector.

Although practical and experimental skills seem to be undervalued in Croatia, this study confirms the findings of previous research about the importance of transferable skills for the engineering profession [4, 6, 24]. Croatian employers seem to concur with their international colleagues, ranking several components of professionalism (the highest ranked, the third and the fifth item), lifelong learning (the second highest ranked item), ethics and responsibility (the fourth top-ranked item) and teamwork (the sixth) as some of the most important skills.

Furthermore, in the referenced literature, soft skills are considered just one part of wider non-technical dimension in engineering education aimed to foster an engineering identity and habitus, which include notions of engineers who are broadly educated, aware of the world around them and who responsibly deliberate their roles in society. In that sense, Krawczyk and Murphy rely on NAE's indications of engineers as "broadly educated, see themselves as global citizens, can lead in business and public service, as well as in research, development and design, are ethical and inclusive of all segments of society" [4]. Therefore, these findings should be taken into account by engineering academic institutions in Croatia, which should lead to a broader range of non-technical classes in their education programs.

However, the importance of professionalism, lifelong learning, ethics and teamwork seem to be valued by employers in somewhat reduced form. For example, it has been shown that employers perceive teamwork as more of a functional than a social situation, i.e., primarily as a more efficient way to attain goals and not so much as a group context in which interaction among the members of the team reflects a culture of mutual respect and understanding. The same "functionality above all" approach goes for communication skills too, where employers do not value negotiation skills as much as other skills pertaining that domain, since an ability to negotiate could imply a need to discuss a range of issues with their employees.

Ethics and responsibility are seen in a similar way. As was mentioned in the previous section, when ethics are linked to professional ethics, they are valued as a top-ranked skill, coming close to the theorized component of professionalism, while, when ethics are linked to environmental and social ethics, they are perceived as significantly less important. Similarly, other non-technical items, such as an understanding of contemporary (economic, ecological and political) problems and general knowledge about national and international events are ranked at the bottom, with employers finding them significantly less important. It should be mentioned that, although employers generally accept engineering skills and learning outcomes designed in accordance with widespread theoretical and empirical background of engineers' employability literature, such functionality might not be shared among other interest groups. In order to encompass broader viewpoints, research on other stakeholders of engineering education (alumni, students, other engineer researchers) should be employed, for education "must be approached as a multifaceted phenomenon, which varies depending on the perspective of the key higher education actors or stakeholders who define them; employers, academics, students and academic and administrative leaders, all of whom potentially assess higher education learning outcome differently." [12].

The present study has also aimed to define the key components underlying skills and competencies analysed. Although all the items were ranked as at least *somewhat important*, in order to shorten the questionnaire, items that either saturated too many dimensions, had low Cronbach values or simply did not make sense considering the solution were deleted. Among the deleted items, those pertaining to the theorized dimension of *problem-solving*, although valued rather highly by employers, were not retained because of their low saturation on different factors. Retained items saturated a solution of 8 dimensions, mostly comparable to previously mentioned research [21, 24], although, in the case of this study, with a stronger emphasis on technical and managerial skills, accounting for 26 % of the explained variance.

Finally, although most of the independent variables analysed resulted in no statistically significant or in slight differences, employers do seem to differ in skill evaluation based on their gender. Generally speaking, women attribute greater value to all skills, both technical and non-technical, than men. Although, when it comes to the issue of recruitment and hiring processes, there is a multitude of studies dealing with gender discrimination and problems women face while trying to get a job, research comparing gender differences in skills evaluation when hiring is unavailable to the best of the authors' knowledge. Since women

represent nearly one third of our sample, and are relatively evenly distributed among owners or members of the supervisory boards, among HR managers or employees of such departments and among managers in other departments, the only clue to aforementioned finding could direct this discussion toward a range of research on gender subject in the field of organisations' studies (leadership, homo-social reproduction, organisational diversity with majority-minority aspects, double-higher standard in status and power etc.).

In any case, results from this study indicate that women fit the theorized dimensions more than their male counterparts, perhaps, indicating a more holistic approach to the hiring process. For example, when evaluating the *communication skills* domain, women tend to give far higher scores to the item measuring a skill to negotiate with clients and employers, giving the domain a roundedness not entirely dependent on functionality. Similarly, items pertaining to the *ethics and responsibility* domain are evaluated as far more important by women than they are by men, showing that the former group finds ethics important not only in the workplace but in regard to the environment as well. Additionally, although still rated only "somewhat important", women tend to value experimenting skills higher than men, which is perhaps more in line with the idealistic expectations of engineers. Finally, it should be noted that women evaluated a vast majority of skills as more important than men did, which could lead to a conclusion that future visions of the engineering profession, as postulated by the NAE, includes not only a declarative but instead a real transformation of the profession where women would not be a minority both in engineering practice as well as in high ranked business positions. On the other hand, such higher scores women tend to have compared to men could be a result of their "minority" status in such profession and leading roles. As has been shown in experimental settings [40], minorities (both racial and gender) in a typically male group context (like that of business and engineering) have to constantly legitimate their value through negotiation and/or hard(er) work [41]. In sum, employers' gender differences with regard to the perception of engineering skills are yet to be further explored.

## LIMITATIONS

Sampling and response rate problems should be noted as the first limitation of this paper. A scarce and outdated database of Croatian employers, combined with the wide range of economic sectors engineers could find themselves employed, made it extremely difficult to define a universe, and practically impossible to make any sampling aside from convenience sampling. Response rate, although the final number of respondents was sufficient for data analysis, was extremely low, due in part to the high number of respondents contacted.

A second limitation of the paper can be found in the explored skills. Although the instrument was constructed and externally validated, which required consulting a large body of previous research, huge variations in specific skills between various engineering disciplines make it extremely hard to explore such skills, which seems to be a constant problem in all consulted literature. As Strauss and Terenzini [25] mention, trying to develop instruments measuring specific skills in the engineering domain would necessitate a rather lengthy instrument, which is "... a clear illustration of the classic 'depth vs. breadth' trade-offs frequently required in instrument development." Given that the response rate was low even with a rather short instrument, there is a strong possibility that even fewer employers would have engaged in the survey if it was longer.

A third limitation is, once again, linked to the set of skills explored. With every single one of them ranking as either somewhat or extremely important, and with their respective standard deviations being altogether very low (ranging from 0,35 to 0,84), a questionnaire implementing such an evaluation method seems of dubious relevance at best. A better method of evaluation

could be found in the means of ranking skills by their relevance, refraining employers from thinking of every skill as extremely important. But seeing as the instrument measured 36 items, such a method would prove to be extremely time-consuming, even if conjoint analysis method would've been implemented. It is important to notice that such high means of skill importance are not specific for this study, but are present in most of the referenced literature and, as such, seem to be a common and recurring "mistake" made by either researchers or employers who seem unable or unwilling to accept (below)average employees.

## **CONCLUSION**

The aim of the presented research was to investigate the extent to which the prevailing learning outcomes in engineering study programs in Croatia meet the expectations of employers and to define the key components of skills and competencies employers consider important. Additionally, the presented research examined whether it is possible to determine differences in employers' ratings of skills and competencies by a number of independent variables. Discussed findings contribute to the recent discussions on engineering skills and competencies as conceptualised in NAE report [6], Krawczyk and Murphy's study [4] and Strauss and Terenzini's nine set skills solution [24]. More precisely, the findings suggest that Croatian employers perceive skills related to professionalism as the most important component among a wider set of transferable skills and significantly more important than other specific technical skills. It turned out that the wider set of transferable skills are seen as the reduced form, mostly through the lenses of their functionality in business and working context. However, further research involving more specified and maybe larger-sized sample could further verify these findings.

With regards to mean comparison within subgroups, the findings suggest the significant gender differences among employers, with women seeing almost all the theorized dimensions as more important than men. We interpreted these differences as indicators, which point to the more holistic approach to skills among women and which correspond to the recent demands of engineering skills in the contemporary world. Still, further research is welcomed in order to verify these findings in more detail.

Finally, exploratory factor analysis resulted in 8 dimensions, describing "employability skills", which explains 62 % of the overall variance among the 29 items. The principal component gathered items marking technical and managerial skills, and explaining more than a quarter of the total variance. Although the retained dimensions are mostly in line with the results of related research, some of them seem to be less recognised by Croatian employers than by their counterparts in other countries. Even though, this research explained almost two thirds of the total variance, further research would be needed to additionally explore other possible dimensions of engineers' employability.

## **REMARKS**

<sup>1</sup>Which was the most recent year when making the sample.

<sup>2</sup>While 21 in total, the category "Extraterritorial organizations" was not included in the sample, as the focus of this research was employability within the Croatian borders.

<sup>3</sup>9 dimensions were conceptually and theoretically clear, and mostly previously confirmed by different studies mentioned in the conceptual background section, while the "+1" was added to further explore some attributes that could not be fitted in one single dimension, and labelled as "other".

<sup>4</sup>Because of the positive skewness of the whole questionnaire, a more extreme approach will be undertaken while interpreting data since it would be of no significant contribution to simply list all the researched skills and write that "Employers value all skills".

<sup>5</sup>“Ability to work under pressure (deadlines, downsizings, demanding clients...)” for the former, and “Design of practical solutions” for the latter.

<sup>6</sup>“Conscientiousness and ability to implement rules of the profession” being the exception.

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# RELATIONSHIP BETWEEN LEAN AND GREEN MANAGEMENT IN CROATIAN MANUFACTURING COMPANIES

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## ABSTRACT

The goal of this article is to explore the link between lean and green management, reasons for their implementation, their effect throughout the whole life cycle, as well as the current state of use of lean tools, economic and environmental indicators in the context of Croatian manufacturing companies. A semi-structured interview was used in this research. As a result, the frequency of economic and environmental performance indicators and lean tools in Croatian companies has been defined, as well as the reasons for the implementation of lean management. Additionally, the understanding of the use of Life Cycle Assessment methods, environmental standards has been obtained and the integration of lean and green management in Croatian companies has been explored. Further on, results were compared to the similar study done in the UK. Finally, it can be concluded that the integration of lean and green management is not yet sufficiently present in manufacturing companies, although there are cases in which these two approaches are integrated, primarily in the process and food industry. It is for these reasons that in the integration of these two approaches lies great potential.

## KEYWORDS

lean management, green management, product life cycle, manufacturing management, environmental management, ISO 14001

## CLASSIFICATION

JEL: L60, R11

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## INTRODUCTION

Sustainable development is a very important topic addressed by governments, the scientific community, and increasingly business entities. According to the Brundtland Commission [1], sustainable development is defined as a development that meets the needs of the present without compromising the ability of future generations to meet their needs. Managing the economic aspect of sustainable development is a well-known fact, and so far this aspect of the business has been given the greatest attention. Each company must keep track of their economic indicators, if not for the sake of improvement of their own processes, then because there are laws and reporting obligations to government and administrative bodies, such as financial or tax administration agencies. Economic performance indicators can be divided into three categories [2]: operational indicators, market indicators and financial indicators. Environmental indicators monitor the impact of the activities of a particular company on the environment. There are different standards such as The European Eco-Management and Audit Scheme System (EMAS), ISO 14001 and Global Reporting Initiative (GRI), which have defined the majority of available environmental indicators in different categories (e.g. Electricity usage, Water usage, Industrial waste, etc.).

Businesses and, specifically, manufacturing companies have high potential to reduce their impact on the environment and this fact has been recognized by the United Nations (UN) in its 2030 Agenda for Sustainable Development [3], where they outlined the achievement of sustainable consumption and production as one of the main goals. One of the principles that will guide the direction of the Republic of Croatia toward sustainable development is the promotion of sustainable production and consumption. Sustainable production is, therefore, recognized as one of the foundations of sustainable development [4]. While earlier the compliance with environmental regulations has been considered an additional cost [5], today, the creation of economic sustainability through environmental sustainability is an increasingly successful strategy for many businesses [6].

The opinion of the European Commission is that certain progress has been made in solving the problems of consumption and production, but fundamental changes and significant improvements are still needed in practices of extracting natural resources and the production, distribution, use, and disposal of products [7]. This can be achieved by aligning production models with environmental management [8]. This change can be further stimulated by tools that simultaneously deal with the future and the current state, emphasizing continuous improvement [9].

In manufacturing companies, the problem of energy efficiency and resources use is becoming increasingly important [10]. The efficiency of processes and resource utilization has, for many years, been in the focus of researchers in the field of operations management, and one of their main conclusions was that the modern production systems are expected to be lean and sustainable at the same time.

Companies, today, use different improvement approaches in production management to improve their company-specific production systems and reduce their impact on the environment [11, 12]. Because of a large number of possible approaches, it is difficult for management to decide which of them they will use. Of all the approaches aimed at increasing efficiency, the most famous is the lean management or lean production and as such, it is often used as the basis of the company-specific production system [11], while the common name for the approaches aimed at reducing the impact of the business on the environment is green management or green manufacturing.

The lean manufacturing approach has become an integral part of the manufacturing environment in the United States over the last four decades [13], but also the world's leading

manufacturing strategy [14], through various approaches based on Japanese philosophies (Just-in-time (JIT), Kanban, Kaizen, Toyota Production System (TPS) and other). The concept of lean production has evolved from the TPS [13] into management philosophy, which focuses on increasing customer value by reducing non-value-added activities and waste time from the value chain or through their complete elimination [5, 14-21]. The long history of lean management has resulted in the fact that there are currently many different tools of lean management. Although there is a large number of differently named tools, they often identify the same or similar tools.

The scientific field regarding green manufacturing has not yet been sufficiently investigated, so this same name is often given to other strategies used in companies, such as [16] industrial ecology, industrial symbiosis, eco-efficiency, three pillars of sustainability, eco-effectiveness, natural capitalism, natural step, biosphere law and others. One of the possible indicators of the implementation of green manufacturing in the company is the implementation of environmental standards, such as EMAS [22] or more well-known ISO 14001 [23] standard. The relevance of the implementation and certification of ISO 14001 has been extensively analyzed in academic literature [24, 25] and there are three most common indicators influenced by ISO 14001 [24]: environmental impact, efficiency, and profitability.

These two approaches in companies usually tend to operate as separate systems, often having opposing priorities and, if treated separately, it could happen that these approaches compete for the same organizational resources, resulting in frustration and unexpected results set in company goals [26]. Therefore, the question “Can additional synergic effects be achieved if these two approaches are used together?” arises.

Recent research have been focused on seeking the relationship between initiatives focused on the increase of production efficiency and those aimed at reduction of environmental impacts, under the common name of lean and green manufacturing [27-32]. From a managerial perspective, lean production and environmental management practices are synergistic, considering their focus on reducing waste and inefficiencies [17].

The logic behind the lean thinking with an emphasis on the seven major wastes could be redesigned and integrated into the system concept of sustainability. In the literature, examples that the application of lean management principles [13] increases the competitiveness of the company that is applying them are found, while on the other hand, the influence of lean management on the manufacturing impact on environmental indicators [33] is less known and needs to be further explored. Lean production is associated with removing the waste from the production process [13], and in order for this process of waste reduction to be complete, it is necessary to supplement the list of lean wastes with environmental impact wastes. It is important to note that some literature sources indicate that the implementation of lean and green programs improves business results [5, 34]. Yang et al. [17] conducted a study on a sample of 309 international manufacturing companies, and results of his research suggested that experience in lean production is positively correlated with environmental management practices. The Environmental Protection Agency (EPA) listed six benefits that an organization can enjoy if it coordinates lean and green initiatives [35]:

- cost reduction,
- a shorter length of the process flow and reduction of lead times,
- reduction of risk of non-compliance with laws and regulations,
- meeting customer expectations,
- improving environmental quality,
- improving morale and employee engagement.

The literature review revealed that companies have different motives for initiating improvement activities such as lean and green manufacturing, and the most common motives are related to improving quality, increasing productivity and reducing costs [36], and implemented improvements ultimately lead to increased competitiveness.

Improvements that are implemented through lean and green manufacturing initiatives do not affect only the company in which they are implemented but also the lifecycle of the product. The greater impact of applying lean principles throughout the lifecycle of products has not yet been thoroughly investigated and understood [14]. Consequently, it is necessary to investigate how the application of lean principles affects the green (environmental) indicators, but also the indicators related to the life cycle of the product [37], which could be achieved by using the Life Cycle Assessment (LCA) methodology [38, 39]. Life cycle assessment is a structured, comprehensive and internationally standardized method for quantifying all significant emissions and resources used and associated environmental and health impacts, as well as resource exhaustion problems associated with the entire lifecycle of any product or service. Life cycle perspective facilitates efforts of manufacturing companies to identify opportunities for improvement in their system, but also through all phases of product life cycle [40]. LCA is also a decisive and powerful auxiliary decision support tool that complements other methods needed to make consumption and production more effective and efficient. An integrated approach to lean and green manufacturing that considers impact throughout the lifecycle of the product and the application of the LCA method has the potential to create positive synergistic effects while simultaneously increasing efficiency and reducing environmental impact.

Taking into account the above-mentioned findings, it can be concluded that the area of lean and green manufacturing is the active subject of scientific research, but the relationship between these two approaches is still not fully defined. Although from the perspective of each individual approach there exist numerous studies, there is still the lack of action research carried out in manufacturing companies. Considering literature review and discovered gaps, the goal of this article is to explore the link between lean and green manufacturing, reasons for their implementation, their effect throughout the whole life cycle, as well as the current state of use of lean tools, economic and environmental indicators in the context of Croatian manufacturing companies.

## **METHODOLOGY**

The methodology we used consisted of three steps: (1) literature review, (2) development of the semi-structured interview (SSI) and selection of respondents, and (3) analysis of SSI.

## **LITERATURE REVIEW**

In the first phase of the research, the available literature on the research subject has been analyzed, including scientific and professional papers about lean and green manufacturing, as well as doctoral dissertations published on this topic. The information obtained by reviewing the literature has been used to determine the most frequently used economic performance indicators and performance indicators related to environmental performance, as well as the most commonly used lean management tools for subsequent comparison with results. The literature review was also carried out to gain a perspective of the current research in the area of lean and green manufacturing integration.

Today, numerous studies are being carried out in the area of operations management and production, but there is still a lack of studies in which the researcher goes directly to companies to discover common problems firsthand, but also to establish relationships

between research areas. Based on an extensive analysis of literature in the field of lean and green management and the nature of the problem being investigated, we decided to use the semi-structured interview method.

## **DEVELOPMENT OF THE SEMI-STRUCTURED INTERVIEW AND SELECTION OF RESPONDENTS**

In the second phase, a tool for conducting research with semi-structured interview has been developed. In this study, semi-structured interviews were used to further clarify the information obtained from the literature on the relationship between lean and green manufacturing, but also to better understand the links between lean and green management in manufacturing companies, taking into account the environment in which businesses operate. Qualitative research is appropriate in situations where a researcher wants to understand the meaning given to events and situations by the research participants, and it takes into account the context in which these events and situations occurred, which is very important in the case of implementation of lean and green manufacturing.

The semi-structured interview method has already been used in similar research carried out in the UK, where Biggs [41] investigated the connection between lean and green manufacturing, and Frost [42] studied drivers and barriers in the application of ISO 14001 standards. Kurdve [43] used a semi-structured interview method to explore the use of lean and green manufacturing tools in Sweden. Torres Jr. and Gati [44] in Brazil, Wu et al. [45] in China, and Wiese et al. [46] in South Africa also used a semi-structured interview method for lean and green manufacturing research.

Interview questions were defined, taking into account the information obtained during the review of the literature, given that some authors [21] recommend using already defined sets of questions to allow for later comparability of the results, but we also added additional questions that allow for a better understanding of the current situation. To define SSI, questions we used the questionnaire developed by Biggs [41] with the interview protocol supplemented by additional questions related to the application of LCA methods in companies and questions about the use of IT support system for lean and green manufacturing approach. There were 14 questions on the subject of lean production (L), 11 questions on the subject of green manufacturing (G) and 3 questions on the integration of these two approaches. Most of the questions were open-ended, with the exception of question L-12, which is concerned with the assessment of a company's leanness and question G-1 about a company's environmental sustainability, which were on the Likert scale. There were no direct questions regarding economic and environmental indicators, as we wanted respondents to mention indicators themselves as part of the response to other questions. We used a direct question about lean tools they have been using, and also questions about the effect of lean production on environmental indicators.

The emphasis of the semi-structured interview was on the discovery of connections between lean and green manufacturing in a specific company from the perspective of people involved in the production improvement or those directly responsible for production management. Companies in which the study was conducted were selected based on their experience in implementing lean management. The main criterion was that the company had more than one year of experience in implementing lean management. One of the authors is actively involved in the organization of the GALP Conference since 2011. That annual conference brings together experts from the area of lean management, so the network of acquaintances from the conference was used in selecting the respondents, but also a "snowball" concept was used when respondents suggested companies for an interview. The respondents were first contacted by phone, where the purpose and methods of the research were explained to them,

followed by an email with details of the interview mentioning that the questions would be from the area of lean and green manufacturing and their relationship. Respondents were informed that the interview will be recorded if they will agree to it and that the data from the interviews will be analyzed as anonymous.

## **INTERVIEW ANALYSIS**

The analysis is the most complex aspect of the semi-structured interview method. The researcher must find useful insights from a large amount of data that will benefit the research purposes without being biased in the analysis of answers. The interview analysis consisted of several steps. All the interviews that have been recorded were transcribed using a piece of software called "*Express Scribe Transcription Software*". All the interviews were then analyzed by initially coding the concepts that are connected to lean and green management to find the frequency of their occurrence in all interviews. In the third step, responses were analyzed by listening to each interview and tracking the records in order to draw the main conclusions regarding the application of lean and green manufacturing in enterprises as well as their possible integration. The results of the interview analysis are presented in the following sections. To avoid bias in the conclusion, they were based on at least 3 or more responses of respondents whenever possible. In case there were findings that only appeared in one interview, this rule was not used since it could have led to the possibility of missing out on important discoveries, which we wanted to avoid. When it comes to research involving people, it is expected that out of 10 respondents not all of them will have the same opinion. To achieve the objectivity of the investigation and to avoid author's bias in topics arising from the analysis of the interview, the author has done his best to also describe negative cases, i.e. examples of respondents' answers that differ from the opinions of the majority.

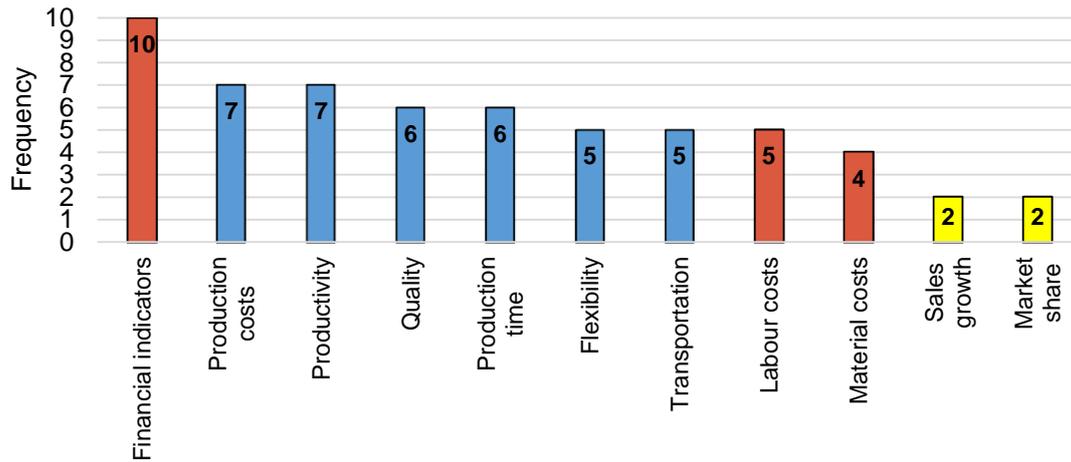
## **RESULTS**

The sample consisted of 10 respondents all from the manufacturing industry. Most respondents come from medium (6) or large (3) enterprises, and only one respondent came from a small business. This classification was carried out in accordance with the European Commission regulations [47] on enterprise aid categories, where the classification of companies is mentioned. Most of the interviews come from companies that have four or more years of experience in applying lean management, while only one company applied lean management for 1,5 years. All the respondents had managerial positions, such as production directors, executives, continuous improvement managers, sector directors, board members and quality managers, health, safety and environment managers. Majority of the interviews were recorded, two interviews were carried out using only notes; one of the notes was handwritten and the other typewritten using a computer. In one interview, half of the interview was recorded and the other half, the notes were taken. A detailed description of the respondents is given in the Appendix of this article.

The results of the interview analysis are grouped according to the topics that have been crystallized through the research. A total of thirteen different topics were identified.

## **FREQUENCY OF ECONOMIC PERFORMANCE INDICATORS**

Throughout the interviews, the respondents mentioned 35 different economic performance indicators. Figure 1 shows the most common economic performance indicators that an enterprise monitors. It is important to note that not all the indicators companies use are captured, but only those that were directly or indirectly mentioned during the interview. Those indicators should be the ones that are the most important to the companies.



**Figure 1.** Frequency of economic performance indicators.

As is shown in Figure 1, the respondents most often speak about financial indicators, although it was common that they did not specify specific financial indicators but stated them generally as essential for tracking during the implementation of lean management. Some of the financial indicators mentioned by the respondents were an increase in the income over the years, as well as realized financial savings through the implementation of lean initiatives.

### What is Lean Management for Companies

When conducting a semi-structured interview, respondents were asked to explain in one sentence what the principles that make up lean management are. From the interviews, several key terms the respondents used to describe lean management were drawn: continuous change, lean is Kaizen, change to better, continuous improvement in all segments, set of tools, reduction of all wastes, optimization of processes, flow, elimination of all non-value adding operations, recognise system areas for improvement in short time, well-organized company with clear goals, constant and continuous learning and improvement, recognition of waste, continuous process improvement.

### Reasons For the Implementation of Lean Management

By analyzing the interviews, information was obtained on the reasons why companies usually decide to implement lean management. In total, 23 reasons were recognized by the respondents as drivers of their lean management implementation. Only the reasons mentioned 2 or more times are shown in Figure 2.

Cost reduction was recognized as the most common reason for implementing lean management in Croatian companies.

### Lean Management Tools Used in Companies

Through interviews, each respondent was asked which lean management tools the company is currently using or had used. Figure 3 shows summarized responses about the frequency of lean management tools used in Croatian and UK companies.

5S is recognized as the most commonly used lean management tool in Croatian companies, while the same category in UK's companies includes 5S, VSM and Kaizen.

### Importance of a Custom Approach to Implementation of Lean Management

Respondents P2, P3 and P5 talked about the importance of a customized approach to implementation of lean management. Respondent P5 mentioned that the meaning of Just in

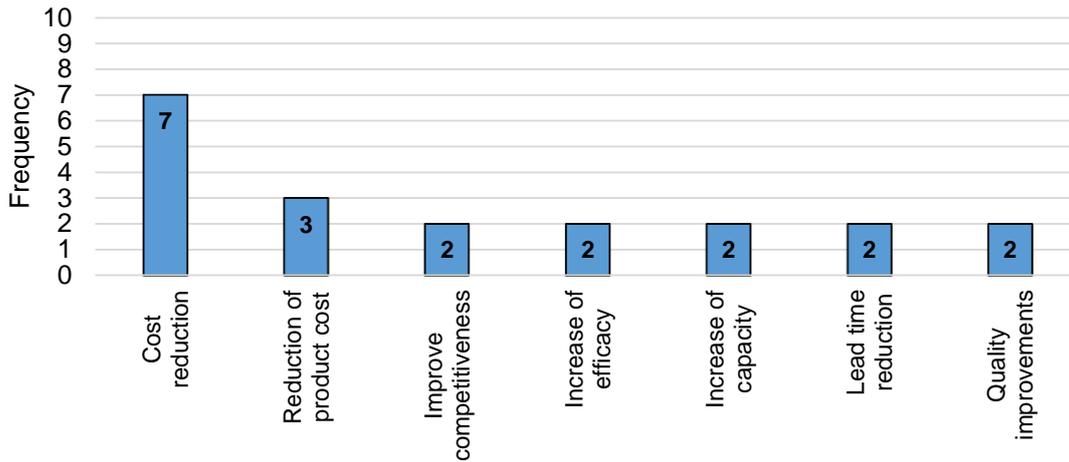


Figure 2. Reasons to implement lean management.

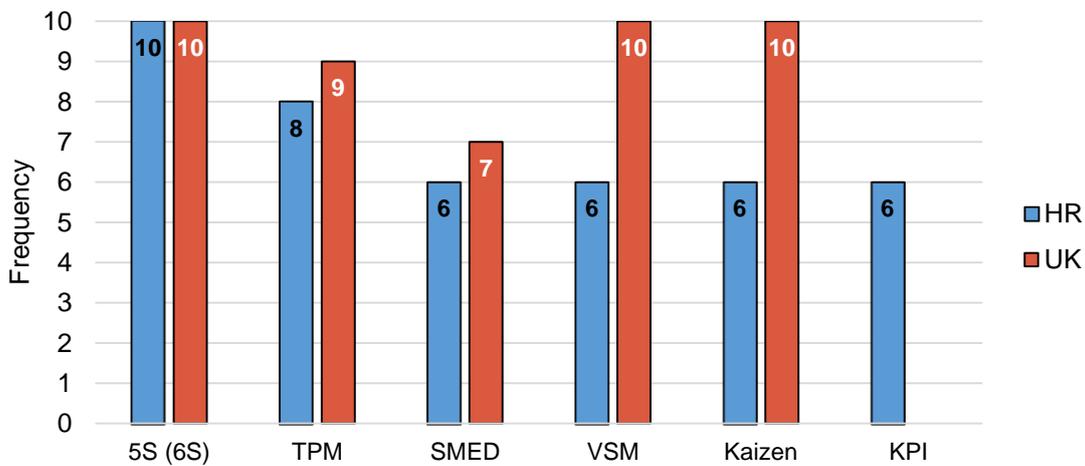


Figure 3. Frequency of lean management tools in the interviews.

Time manufacturing is not the same in Japan and Europe or, more precisely, in Croatia. Respondent P2 stated that lean management is not something that can be implemented by copy-paste principle. In order to achieve a customized approach, companies (P2) use services of external consultants. In some cases, a set of tools to be used in companies are imposed by the parent company (P7, P9). The parent company normally leads the implementation of lean management across all businesses. Sometimes companies start the implementation by following a well-known methodology, but over time the methodology is adapted and only the tools that bring the most benefits to a particular company are used (P10). Finally, respondent P3 further stated that for the success of the implementation of lean management, trust should exist in the company, which can be achieved through open communication, transparency and fair wage.

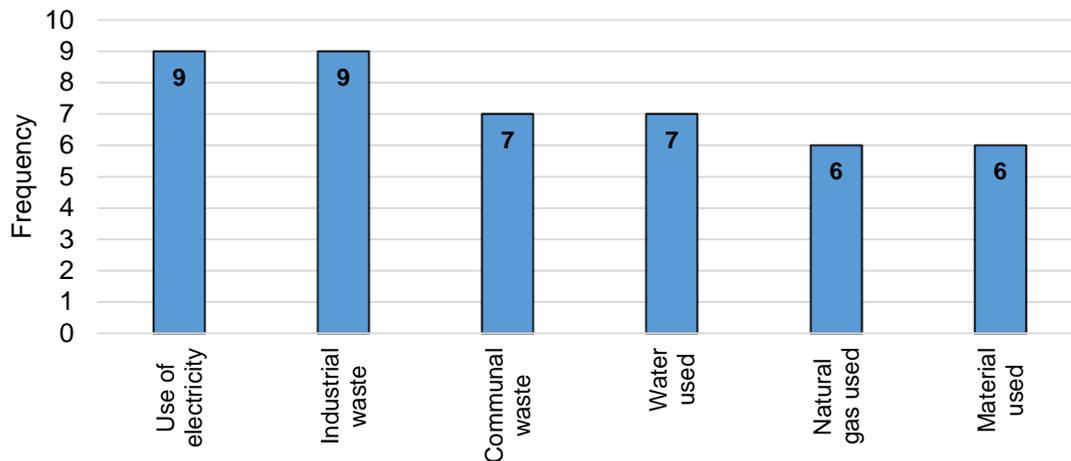
### The Integration of Lean Management in Existing Standards

In several cases, respondents mentioned that there is integration of standards in their company. Therefore, respondent P1 noted that they are currently working on the integration of the 3 standards they use and each contains a risk analysis in order to have only one risk analysis at the end. Respondent P3 mentioned the integration of standard procedures developed within the lean management to ISO 9001 standard procedures, and the reason is that in the case of revision of the ISO standard, they will have to carry out the revision of the standard procedures developed within the lean management. Respondent P8 also noted the integration of standard procedures derived from the lean management in the ISO 9001 system, and as a main reason, mentioned the need to reduce the need for duplicate reports.

### **Frequency of Environmental Performance Indicators**

Companies have a legal obligation to take care of the environment, and there are mandatory indicators that must be monitored and reported. Summarized environmental performance indicators and their frequency are shown in Figure 4.

As the most common environmental indicators in Croatian companies, the use of electricity and industrial waste are recognized.



**Figure 4.** Frequency of environmental performance indicators.

### **Relationship Between Environment and business**

Most companies rated their business as friendly to the environment (median 8, average value 7,75). Throughout the interview, all the respondents stated that they have an organized way of collecting, sorting and disposing off waste in the company, and waste disposal is left to companies specialized in that business.

### **Use of LCA methods and Ecological Certificates**

In order to find out whether companies are thinking about the impact of their products over the product lifecycle, respondents have been asked a question about the impact of lean management activities on the product lifecycle as well as whether they use LCA in their business. Only one respondent (P2) said that they used the LCA method, although he noted that it was still related to individual initiatives and not the method the enterprise used systematically. Furthermore, P4 stated that this was under the jurisdiction of marketing, and P9 stated that the products were monitored through their lifecycle only financially, although, for example, the impact of all business activities through the carbon footprint was monitored in the same company. Other respondents responded negatively to this question.

### **ENVIRONMENTAL STANDARDS**

According to the data obtained through the interviews, 6 out of 10 respondents stated that their company had ISO 14001, and of the remaining four, two mentioned that they are planning to implement ISO 14001 in the next two years, while 2 respondents said that they would implement ISO 14001 only when asked by the customers. None of the respondents mentioned EMAS.

### **Environmental Improvements – an Opportunity for Companies**

All respondents to the question, whether they consider environmental improvement as a cost or an opportunity for their company, responded that they see it primarily as an opportunity.

The interview analysis has crystallized several reasons why respondents consider reducing the impact on the environment as an opportunity. The first reason is that their customers are seeking information on certificates related to environmental impact, such as ISO 14001 and information on work safety. The second reason is that it enables businesses to reduce energy consumption and reduce waste, and if waste is sorted, it can be sold. The third reason is that companies want to create a healthy environment in which they work through environmental activities. The fourth reason is that reducing the impact on the environment by reducing scrap in processing materials creates savings for the company. Respondent P9 mentioned the concept of “zero waste”, which should enable companies to eliminate all waste arising from their processes, although, as stated by respondent P4, initially, these initiatives require certain investments. Certain companies use IT systems and the environmental balance sheet to monitor changes in environmental impact indicators. Respondents P2 and P10 stated that they make an environmental balance sheet and respondent P7 stated that they use the IT system at the group level to report on the impact of the business on the environment. Respondent P9 stated that they have a local environmental impact monitoring system that reports at the group level, and sometimes the environmental group regulations are much stricter than the regulations by the environmental laws in the Republic of Croatia.

### **Integration of Lean and Green Management**

Through the analysis of the interview, it was obtained that only 3 out of 10 respondents (P4, P6 and P9) mentioned savings related to green business when they talked about lean management. When asked directly about the impact of lean management on the environmental performance indicators, all respondents agreed that the implementation of lean management results in a reduction of the environmental impact.

Specifically, P1 stated that there was a decrease in the consumption of materials and the use of tools in production. Respondent P2 stated that these indicators were not tracked within the lean management, but since there is an environmental balance sheet, it is possible to find out from it. P3 believed that it results in stock decrease and waste reduction, though he was not sure how, and indirectly results in reduction in all of the mentioned impact indicators. Although they do not monitor the consumption of water and electricity, he also considers that there is a reduction in those segments. Respondents P4, P6 and P9 believe that there is a reduction in environmental indicators mentioned in the question. Respondents P5 and P9 emphasized that emissions to the air are reduced. Respondent P7 stated that there was a decrease in the consumption of resources, materials and electricity, and also stated that there was an increase in water consumption, which respondent P1 agreed to, but only in absolute terms and the reason was the increase in volume of production, while the consumption of water per unit of product produced decreased. Respondent P10 believes that, among other things, waste, resources and materials are reduced. People satisfaction was mentioned by P8 as one of the most important indicators along with all the above-mentioned.

The aim of this research is to investigate the connection between lean and green management in manufacturing and, accordingly, respondent P1 believes that by systemic approach and integration of parts of the system, a company can achieve greater competitiveness and increase productivity. He particularly emphasized the importance of care for energy independence of the company, which is evidenced by the fact that the introduction of new technologies will increase the dependence of companies on energy and hence the company's imperative to work on energy sustainability. Introduction of solar electrical systems can certainly help. Dependence on external factors can also be reduced through the use of waste heat from the machines for the preheating of water. Respondent P2 considered integration of lean and green as a good idea, especially since some lean management tools have a direct

impact on the environment. Respondent P3 agreed with P2 and argued that whether we emphasize it or not, lean management has a positive impact on the environment. Respondent P4, however, argued that lean tools could be used to reduce the impact on the environment, although he claimed that we are generally delayed with the introduction of lean tools in general because while digitization is being carried out in the world, we have not yet established our processes and it is not worth digitizing bad processes. Respondent P5 believes that besides reducing the impact of the business on the environment, cash benefits should also be expected when introducing lean tools and taking into account their impact on the environment, primarily through the return of the product back to the manufacturer. Respondent P6 pointed out that there is still a lot of space for implementing lean management, not only in manufacturing but also in service industry, while P7 said that using lean tools affects the sustainability of production and the environment. Respondent P8 supported the idea of integration and stated that businesses can only succeed if they monitor key business and environmental impact indicators. Respondent P9 believes that there is a causal link and that he does not agree with the statement that lean management only affects economic indicators, but it has, as well, an obvious impact on environmental indicators, while P10 considered that the main point is in the increase of the competitiveness by making a quality product, for which there is a market, with as little resources as possible.

### **The Impact of Improvement in Production in Other Phases of the Lifecycle**

By analysing the interview, it was found that most respondents believe that improvements in production could have an impact on other life cycle phases, but they were often not sure in what way exactly, although they have recognized several possible ways. Thus, respondent P1 believes that it certainly has an impact but has not been looking at it from that perspective. Achieved improvements can help in the use phase by reducing complexity of the product, which can result in reduced weight and easier assembly. Respondent P2 also thinks that it has an impact by increasing the quality, which then extends product life expectancy, and waste reduction decreases the impact of business on the environment. Respondent P3 argued that improvements reduce waste and at the same time affect cost reduction and indirectly reduce environmental impacts. Respondent P4 also believes that improvements in production have an impact on the environment because by implementing improvements, they reduce energy consumption and scratch, but he did not mention the impact of these activities on the product lifecycle. Similarly, just like respondent P4, respondent P5 mentioned that there is an impact on production but does not mention the impact on the other phases. P6 mentioned that there is no impact on the use stage of a product lifecycle but only in the production phase. Respondent P7 thinks that the production cycle, from order to delivery, is decreased, while technological preparation and design may affect the use phase. Respondent P8 agreed with respondent P7 and believes that the use phase can be affected by the creation of functional products. Respondents P9 and P10 believe that the use stage is affected through an increase in quality, and the impact of improvements in production is possible through waste reduction, which is considered by respondent P10.

### **Negative Cases**

Some respondents, including P4, P6, P5, pointed out that the introduction of lean management resulted in a reduction in the amount of transport, mostly due to delivery optimization, better machine layout and transport intensity. On the other hand, respondent P1 noted the indirect linkage of lean management with increasing transport costs. Namely, the company recently opened a new plant as a result of the expansion of production, and which the respondent attributed to the results of the activities of lean management. As the new plant is not close to

the existing one and certain products are manufactured at both locations, there is an increase in transport costs and, therefore, associated emissions in the air.

As part of the interview, respondents were asked whether environmental improvement is an opportunity or a cost for them, and most respondents have confirmed that it is an opportunity, although there is an opposite opinion. Some respondents consider the reduction of environmental impact also as a cost and as an opportunity for their company. Respondent P3 stated that it is easy to define the cost, but the opportunity is not so obvious. Respondent P4 stated that while it is initially costly, the return on investment starts coming in after a very short time.

## **DISCUSSION AND CONCLUSION**

The respondents are from companies in various industries, both of Croatian and foreign ownership, and from companies of different sizes. The greater representation of medium and large companies in this research arises from the fact that small businesses usually have their production organized as workshops and, thus, do not apply lean management, although the P6 example shows otherwise, but it must be taken into account that this company is 50 % owned by a foreign group, which could be one of the reasons for the implementation of lean management.

Enterprises monitor different economic and environmental performance indicators – some of them follow the force of the laws and the obligation to report regularly either to the economic or environmental indicators, and some indicators are monitored to better manage their processes to ensure their sustainability in economic and environmental terms. When discussing economic performance indicators, respondents talked frequently about financial indicators, including among others, increase in the amount of income through the years, as well as the financial savings achieved through the implementation of lean initiatives.

Lean management for respondents represents a continuous (never-ending) process of learning and constant improvement through the involvement of all employees, by recognizing and then removing all activities in the process that do not add value from the customer's point of view. All this is done using lean tools. The goal of lean management is to meet customer requirements in an efficient way, which creates a well-organized company.

When looking at the reasons the respondents stated as motivation for their businesses to embark on the lean management implementation journey, the most common reason was cost reduction. Among the more frequent reasons, there is also an increase in quality, and respondents also mentioned increasing the ability to meet customer requirements and better organization of the enterprise, which is in line with the research that was carried out by Terziovski i Sohal [36] in Australian companies. Some of the mentioned reasons are directly related to each other, such as reduction in production costs, which directly affects the reduction of the product's manufacturing price. One characteristic of all the reasons is that they can increase the company's competitiveness on the market. If the results are compared to those of Biggs [41], which she obtained by doing a similar semi-structured interview in UK companies, it can be seen that in Croatian companies the reason for cost reduction is mentioned in 7 out of 10 interviews, while Biggs has reported that it was mentioned in 6 out of 10, which does not represent a significant difference, and it can be concluded that for both Croatian and UK companies, the biggest emphasis during the implementation of lean management is on cost. Interestingly, only one respondent from Croatia stated explicitly that the reason for the implementation of lean management was pressure from the owners, the international company, which was also the case in the research conducted by Biggs. From this, it can be concluded that companies have a desire for continuous improvement in order to reduce costs and achieve better market position, and the biggest influence on the implementation of lean management comes from the market and customers. To achieve this,

companies have to involve all the employees in the process of continuous learning and improvement so they can recognize and remove from the process all the activities that do not add value from the customer's point of view.

Respondents mentioned the use of lean tools, and by analysing the interview, it was found that 39 lean tools were used by companies. When research is carried out in different manufacturing companies, there is a problem of standardization of terms, which was also the case with the definition of tools used, since different names can be used in companies for the same tool. As has been written earlier, it is possible that not all the tools used by companies are registered in the interview. But for those tools that were mentioned by the interviewees, it can be concluded that they are important to them. Of all the tools of lean management, the most common is 5S and it is mentioned in all the interviews. The presence of the 5S tool in all companies that apply lean management is expected, since 5S is one of the basic tools of lean management and one of the first tools that is used at the start of the lean management implementation. One of the reasons why companies start with the 5S implementation is because of its simplicity and visual impact, which means that the 5S results are immediately visible on the shop floor. On the other hand, 5S is one of the simplest lean tools and is often used by companies to test if they are ready to devote themselves to continuous improvement activities. TPM is another tool companies implement most frequently. The reason for such frequency can be found in the company's focus on the utilization of machines. Let's say companies can very easily calculate Return on investment (ROI) of each machine and how much it should be utilized to pay off for the investment. The third most commonly used tool group is SMED, VSM, KPI and Kaizen. In this tool group, attention is more on Kaizen. Sometimes companies use it interchangeably with lean management, but more often, it is mentioned in the context of specific application, such as Kaizen Workshop [48].

If a comparison of the tools obtained through this research and the tools obtained in the UK survey (Figure 4) is made, it can be concluded that the 5S tool is, in both cases, the most represented. Additionally, all the companies in the UK survey used Value stream mapping, compared to only 6 in Croatia. As stated by Biggs [41], Poka-Yoke tool was applied in all companies interviewed in the UK, while in the Croatian companies it was not mentioned at all. Also interesting is the data regarding the application of the One-piece Flow and Cell Production tools, where these two tools are present in most UK companies, while in Croatia they are not mentioned at all. In only one company, a production line was observed, which could be identified as a one-piece flow of the material.

From the data on the implementation of lean tools in Croatian companies, as well as on the basis of the data obtained from the literature, it can be concluded that companies use different tools, and the selection of tools most often depends on the results that a particular company wishes to achieve. The choice of tools can, therefore, be influenced by the methodology that companies follow in the implementation, the advice provided by the consultants engaged in the implementation, and, in some cases, the choice of tools is defined by the group and the local enterprise does not have much flexibility in the selection. Not only tools, but also the entire program of lean management implementation cannot be simply copied from one company to another, but it is necessary to adopt it to the culture and specific environment in which it is implemented. And for the success of the implementation, it is important that there is trust in the company, which can be achieved by open communication, transparency and fair wage. When considering a set of tools that exist in lean management, it can be seen that the choice of tools to be used, in most cases, is left to the company to decide, which can be a challenge, especially for those companies that are just getting introduced to lean management improvement programs. This leads to the conclusion that companies would benefit from a model that would assist them in selecting lean management tools according to predefined

criteria. Criteria for such a model can be defined based on the literature analysis and on the results of the frequency and importance of the individual economic and environmental indicators obtained from the conducted interview.

The use of electricity was recognized as the most common environmental indicator in Croatian companies. This indicator is not always directly related to the environment, but appears also in discussions about the influence of lean management, as was the case in interviews with respondents P4, P6 and P9. The second most common indicator is mainly related to industrial waste disposal, where companies, in most cases, by waste management, consider a disposal of scrap material from the manufacturing. Although it is worth noting that all the companies have a defined waste disposal system, most often defined by the law on environmental protection, but increasingly, the company's strategy to reduce costs by reducing waste by sorting and selling it.

The results obtained show that companies in Croatia do not use the LCA methodology for environmental impact assessment throughout the product lifecycle. On the other hand, in companies that use lean management, 6 out of 10 have introduced the ISO 14001 system and two plan to introduce it over the next two years. It should be noted that although companies use and follow all the rules defined by the ISO 14001 system, if it was not required by the customer, the companies do not carry out official certification. Respondents mentioned that there are certain activities in the companies that integrate different standards, and there is an example of integration of lean management in the existing corporate standards. In this way, the companies reduce paperwork and increase the sustainability of the improvements.

Although reducing the impact on the environment requires certain financial expenses, which are sometimes not so small, most companies consider reducing the impact of business on the environment as an opportunity, primarily in long-term cost reductions, reduction of energy, water, gas and other resources use, reduction of waste, and scrap, taking care of employees, general reduction in the impact of business on the environment and increasing the competitive advantage by obtaining environmental certificates. The best examples of good environmental management practices and environmental impacts come from foreign-owned companies, and the parent company is from Western Europe, where environmental awareness is more developed.

Integration of lean and green management is not yet sufficiently present in manufacturing companies, although there are cases in which these two approaches are related. This connection is present in companies from the process and food industry where electricity, gas, water and other resources account for a large share of production costs. Therefore, it is logical the focus of these companies to monitor and reduce their consumption. This is also why lean management initiatives are connected to the green part of the business. Accordingly, in the integration of these two approaches lies great potential. From the responses above, it is possible to draw another conclusion: companies still do not recognize the impact that improvements in production have on other stages of the product's life cycle, and most of them relate this impact to quality, cost benefit and increase in the product life span. With this in mind, companies need tools that will help them see the impact of their activities throughout the lifecycle of the product, and one of these tools is surely the LCA.

The results and conclusions of this article are based on the data obtained from companies in the manufacturing industry. For this reason, this article can serve as a guideline to other researchers who want to explore the link between economic and environmental sustainability in service companies, as well as government and public administrations. Further, the direction of future research can go toward studying the possibilities of integrating social approaches to lean and green manufacturing.

The area of sustainability of production, both economically and environmentally, will be an increasingly important topic of scientific research, but also of initiatives implemented within the enterprise. This article confirms that there is a link between approaches of lean and green manufacturing, but also that companies still do not sufficiently use the benefits of their connection. In addition, the most frequent lean tools, economic and environmental performance indicators used by Croatian companies were defined, and the results were compared with companies from the UK. During the interview, there were 27 preliminary conclusions, most important of which were mentioned in this article.

Finally, it can be concluded that the integration of lean and green management is not yet sufficiently present in manufacturing companies, although there are cases in which these two approaches are integrated, primarily in the process and food industry. It is for these reasons that the integration of these two approaches has great potential.

## **APPENDIX**

**Table 1.** detailed description of the respondents. SVP is medium sized enterprise, VP-VM – large enterprise in full international ownership, VP – large enterprise, MP-DM – small enterprise in partial international ownership, SVP-M – medium enterprise in international ownership, and VP-M – large enterprise in international ownership.

#	Size	Main business activity	Experience in Lean, years	Interview participant	Interview conditions
P1	SVP	Manufacture of refrigeration and ventilation equipment	10,5	Quality manager	Recorded
P2	VP-M	Manufacture of electrical machinery and devices	6	Continuous improvement manager	Notes only
P3	SVP	Construction, manufacture and sale of machinery	4	Production director	Recorded
P4	VP	Manufacture of food products	4	Production sector director	Part notes / part recorded
P5	SVP	Manufacture of refrigeration units	4,5	Production manager	Recorded
P6	MP-DM	Manufacture of motor vehicles	1,5	Production director	Recorded
P7	SVP-M	Manufacture of metal structures and fabricated metal products	5,5	Production director	Recorded
P8	SVP-M	Manufacture of paper and cardboard products	6	Production director	Recorded
P9	VP-M	Manufacture of drinks	7	health and environment manager	Notes on PC
P10	SVP	Manufacture of metal structures and fabricated metal products	13	Board members	Recorded

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# A MODEL TO INVESTIGATE THE EFFECT OF WORK ETHIC CULTURE ON DYNAMICS OF REWORK IN MANAGEMENT OF PROJECTS

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## ABSTRACT

The present study aims to investigate the effect of work ethic culture on rework in construction projects through a review of literature, surveys, and interviews with project managers. The main research question is what mechanisms can project manager use to balance the costs of personnel training, financial and language incentives, and implementation costs to finish the project with more profit and less rework. In this regard, modelling and data analysis is done using System Dynamics methodology. The results show that by considering work ethic, rework in the project is reduced from 46 % to 39 %. However, the project has been completed with 10 % lower cost and 26 % lower variance. Integrating the issue of rework with the culture of work ethic in the field of project management by at least one exogenous parameter has been studied, while in this study qualitative parameters have been converted to quantitative parameters using fuzzy inference system. The change in management approach to the issue of work ethics and the formulation of human resource strategies of large projects by human resource managers is one of the applications of this study.

## KEYWORDS

work ethic, system dynamics, rework, project management, construction

## CLASSIFICATION

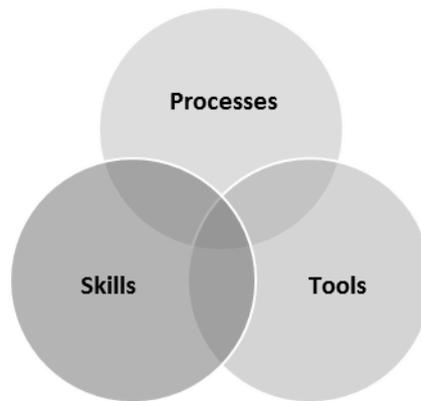
JEL: C61, M12, M54, O22

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## **INTRODUCTION**

Project management is undoubtedly one of the most important and most used branches of management over the past decades [1]. Project management is a combination of “the art of collecting facilities and doing work by individuals in the formal and special organization” as well as “the science of producing and processing vast amounts of information for project planning and control” [2]. The first issue in project management is to ensure that the project is defined with specific constraints. The second issue, is to optimize the allocation of resources and to align the data needed to achieve the project’s predetermined goals [3].

Project management is skills, tools and management processes required to successfully complete a project [4]. According to Figure 1, project management combines processes, tools, and skills, as described below.



**Figure 1.** Project management components [4].

A set of skills: knowledge, skills and experience of specialists are needed to reduce the risk level of the project to increase the probability of success of the project.

A set of tools: various types of tools are used by project managers to improve their chances of success. Examples include templates, registers, planning software, modeling software, audit checklist and revision forms.

A set of processes: various processes and techniques are needed to monitor and control time, cost, quality and scope of the project. Examples include time management, cost management, quality management, change management, risk management and problem management.

Therefore, project management helps us ensure the achievement of project goals and plans, organizes, monitors and controls the necessary resources and tasks for project implementation, such as people, money, equipment, operations, and time of project implementation [5].

Given the role of human resources in all of the above three groups, when it comes to the principles of project management, it is usually the human resource management (HRM) [6]. Approach and perspective of the HRM is regarding the development of human resources to use this force to improve team performance of projects and build the competitive advantage of the organization. Therefore, planning and developing human resources (HRs) of projects is an essential part of HRM in the construction industry. HR planning has been recognized as an important method that focuses precisely on project performance. HR planning generally involves setting formal goals, appropriate strategies and searching for the use of creative HR [7].

An organization’s HRs include everyone employed in a job, regardless of the role they play in the organization [8]. The role of HR in the progress of companies active in the construction and urbanization industry is a central role [9]. Nowadays, changes in the construction and urbanization industry increase, which requires more attention to targeted planning for HRM [10].

Human resource management is directly related to the organization's human resources. These forces contribute to the goals of the organization. If this relationship is a healthy and effective relationship, then this organization will definitely achieve its goals. And if this relationship is based on unethical behavior, then its effects and consequences will prevent the organization from achieving its goals. Therefore, HRM should combine ethics with today's laws to develop work ethic culture in the organization so that it does not encounter any problems in its movement and production and achieves strategic goals by establishing an effective relationship between HR managers and employees of the organization [11].

Managers must ethically create an atmosphere or a healthy environment for employees so that they can increase their production and do not get into trouble in terms of good behavior [12].

Today, many countries in the industrialized world have grown mature, disregarding ethical issues and fleeing social responsibilities and obligations, leading to the disappearance of the firm [13].

Such attention might be attributed to the fact that work ethic, in particular, is believed to reflect an individual's attitudes towards various aspects of work, including preference for activity and involvement, attitudes toward monetary and non-monetary rewards, and the desire for upward career mobility [14].

The importance of this research can be considered from a number of perspectives:

- first, from the point of view of the literature of the subject, on which no specific study has been done so far,
- the next perspective that is examined is construction industry,
- from another perspective, the importance of this research is considering the upstream documents of the country.

Love et al. conducted a study titled "determining the causal structure of rework influences in construction" and examined the effect of rework in construction projects with a simple system dynamics model [15].

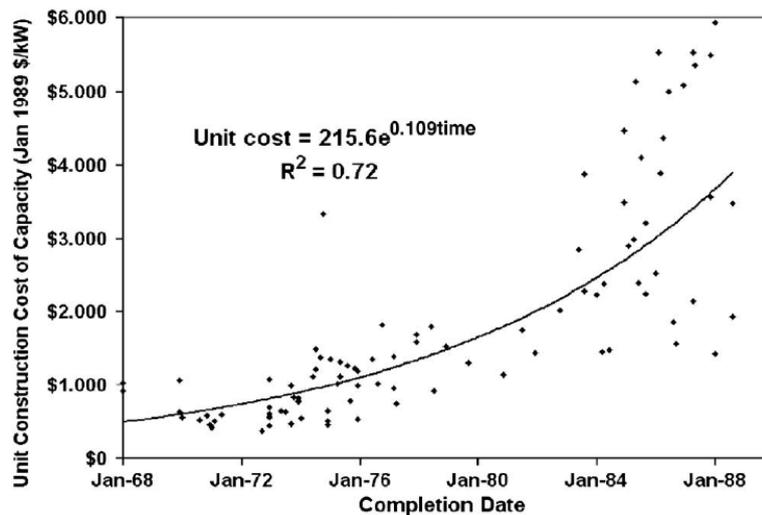
By studying the research on the subject of rework in project management using the system dynamics methodology, it is found that combining these topics with the culture of work ethic that is related to the humanities and social sciences is examined in a superficial way with just an exogenous parameter. In other words, the issue of making the qualitative issues of project control quantitative has not been addressed so far, for which fuzzy methods can be used. In this research, it is tried to do this with the present research gap.

Since the problem occurs in the context of a complex system, while different cultural and social, economic, and technical factors are influencing, in this research, system dynamics methodology is utilized to model different dynamics affecting the problem. System dynamics has the ability to include quantitative and qualitative factors in form of causal loops and it simulates the behavior of model variables during the simulation time. The methodology has been used to investigate complex problems in various field like unconventional oil technology development [16], wind power development [17], oil production [18], production systems [19], climate [20], project management [21], agriculture [22], brain drain [23], social networks [24], etc.

According to the above, the subject of this research is to present a model for the study of the culture of work ethic in the management of Iranian rework in construction projects (because the culture of different nations is different in terms of work ethics and self-control), in which the problem of rework is addressed using a System Dynamics on the basis of discussion of responsibilities and social obligations, i.e. the standard ISO 26000 and SA 8000 (social responsibility) workspace [25]. Research results may also apply to any other construction project, such as a refinery, but the scope of the present work is a building construction project.

External factors such as changes in the scope of the project make it difficult to achieve the project's goals, but the internal dynamics of the project also reduce the ability of project managers to control the project and can defeat a project. A typical example of the internal threats of the success of the project is described as "rework" [26]. Rework is one of the main causes of excessive cost and scheduling [27], which can indicate increasing percentage of progress by a continuous increase in unfinished tasks of the project, while a decrease in the percentage of progress has been achieved that leads to a final failure [28].

Many complex projects, including nuclear power plants, fail due to their delivery time and budget. For example, the construction of the first generation of nuclear power plants in the United States had an average of 239 % variance from its program and experienced an average of 338 % cost increase [29], which is shown in Figure 2.



**Figure 2.** The costs of constructing the first generation of the US nuclear power plant [29].

After reviewing the literature, in Section 2, the research methodology is described. In Section 3, the impact of the work ethic culture on rework is addressed with a systematic approach by providing the definition of the problem, the dynamic hypothesis, the subsystem diagram and the causal loops diagram. In Sections 4 and 5, discussion and conclusion are presented.

## RESEARCH METHOD

Initially, through the study of papers and research on project management and HR rework as a factor in project management failure, factors affecting work ethics culture were identified. Then interviews were conducted with the research population, i.e. project managers, senior executives and senior experts as project experts. In the next step, the data was collected and the modeling was done using the System Dynamics (SD) methodology and, finally, the outputs were obtained. Figure 3 illustrates the steps and problem solving tools in SD.

System Dynamics was first introduced by J. Forrester [30] at MIT as one of the first responses to research weaknesses in operations and other management science techniques. From Forrester's point of view, the research modeling techniques in the operation are only able to have a limited number of variables in a system, and on the other hand, the relationships between these variables are seen linearly. Forrester had a subjective mindset of electrical circuits and servo-mechanisms. He used his knowledge of the theory of feedback control and the use of modern computers to develop methods for modeling and analyzing problems in complex systems. This approach focuses on the dynamic and systemic behavior of the system, and has been developed based on the results of previous studies by Tustin [31] about electrical and mechanical control systems.

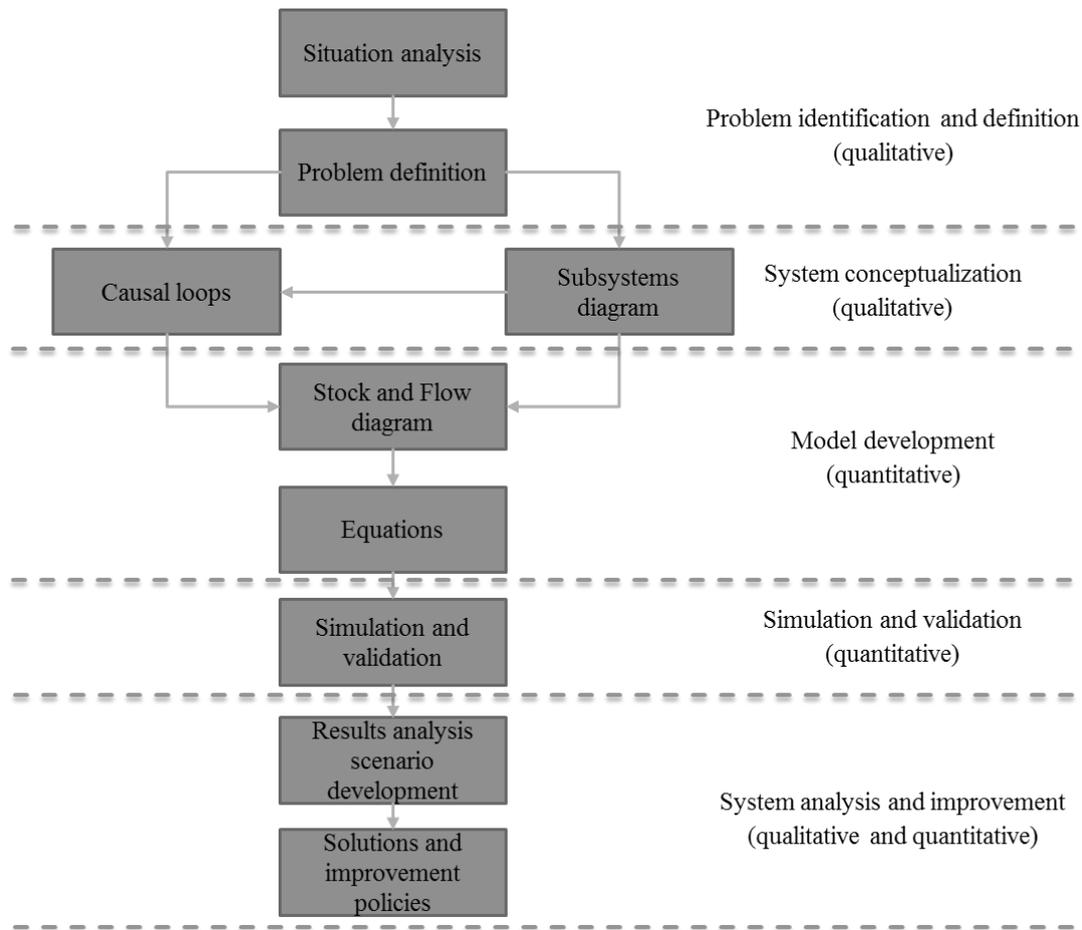


Figure 3. Problem-solving steps and tools in SD.

## MODEL OF SYSTEM DYNAMICS OF THE EFFECT OF WORK ETHIC CULTURE ON REWORK

There are many influential factors in the project management system that have dynamics over time. The major processes affecting this system are the total work done in the project, the remaining work, the work done, and the confirmed and done work. Some of the existing dynamics include productivity, fatigue, overtime working, progress rate, project deadline, expected time, project completion, required manpower, project cost, etc.

Table 1 shows the model boundary chart. The main variables of the model are divided into three categories of endogenous, exogenous, and exceptional.

Endogenous variables are variables whose dynamics are created within the boundaries of the model and the exogenous variables are variables that are externally entered into the model [32]. Exceptional variables are variables that have been studied in literature studies and interviews with some building industry experts, but have been eliminated from the final model due to some limitations such as the lack of officially published statistical data, the politicality of decisions, and so on. These main variables are introduced in Table 1.

### DYNAMIC HYPOTHESIS

The dominance of work ethic culture in construction projects, influenced by motivating factors such as education, financial incentives and language incentives and taking into account the level of education and knowledge and other quantitative social indicators, causes active human resources in the project employ their ability, talent and expertise not only

**Table 1.** Model boundary chart.

<b>Endogenous</b>	<b>Exogenous</b>	<b>Exceptional</b>
<b>1. Remaining work</b>	1. The project deadline (contract)	1. Changes in the project scope
<b>2. Work rate</b>	2. Delay in getting hired	2. Changes in project timing
<b>3. Work done</b>	3. Man hour / activity	3. Changes in project budget
<b>4. The whole work done in the project</b>	4. Overtime working	
<b>5. Verification level of work</b>	5. Amount of remaining initial work	
<b>6. Confirmed done work</b>		
<b>7. Rework rate</b>		
<b>8. Total rework rate of project</b>		
<b>9. Number of manpower</b>		
<b>10. Project cost</b>		
<b>11. Employment rate</b>		
<b>12. Quality of work</b>		

without any control, but although voluntarily in order to achieve project goals, which will reduce the rework of the project, followed by increased project progress, lower cost and higher quality.

The quality of work done in rework in construction projects is very important, so you can expect a successful project by supporting or assisting the workforce in the project. Some of the auxiliary factors are: adequate funding, facilities and equipment that are suitable for doing work [33]. Utilizing human resource talent, creating a climate of ethics and commitment, sharing workforce in productivity, motivating through incentive and punitive factors, establishing healthy relationships between project manager and labor force, and etc. are the prerequisites for the impact of ethic on quality and rework reduction [34]. For example, if there is a good or high investment in human resources education, considering the advancement of technology, the cost savings will eventually be reduced. Project management can morally make the work force to do tasks in an optimum level by creating an ethic charter. It is necessary to note that the characteristics of encouragement and punishment vary in various steps from design to the end of the project. That is why it is seen in the operational phase of the project in the current research.

In the process of increasing motivation, we also see these issues as motivation stimulates people and encourage them to work more effortfully. Workers who have a strong motivation feel more committed and happier in their work. Motivated people are affected by a variety of factors. Each person has basic needs such as food and shelter, which can be obtained by paying money. However, there are many different factors that motivate people. A creative environment can be very stimulating. By empowering people, they can be promoted to improve the process. With more motivation, more work is done to achieve the required results. These people feel that their work has exceptional features. Hence, they are proud of it. So even the amount of absenteeism is very low. For example, if a worker who has the responsibility of a wall drain feels more loyal by reference to his ethics, that wall will be better prepared to carry out other thinning operations. In this place, the needs of individuals are being met by training and encouraging and establishing work ethics.

At the beginning of the project, the project manager has to spend on personnel training to get more profit at the end of the project, while most project managers are unaware of this. In this study, we want to examine rework reduction with the consideration of work ethics and

without its consideration. In this regard, Figure 4 shows the hypothesis of this study in the form of a reference mode for this system. In the presence of work ethic improvement policies, although the organization has incurred more costs at the beginning of the project, but more savings is experienced and the total cumulative cost of the project will be less at the end of the project. In this study, we will examine this behavior by creating a dynamic model.

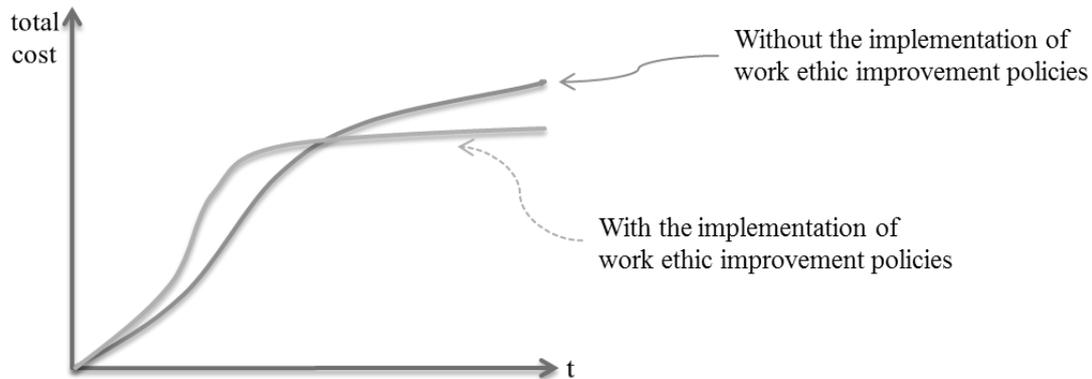


Figure 4. Reference mode.

### SUBSYSTEMS DIAGRAM

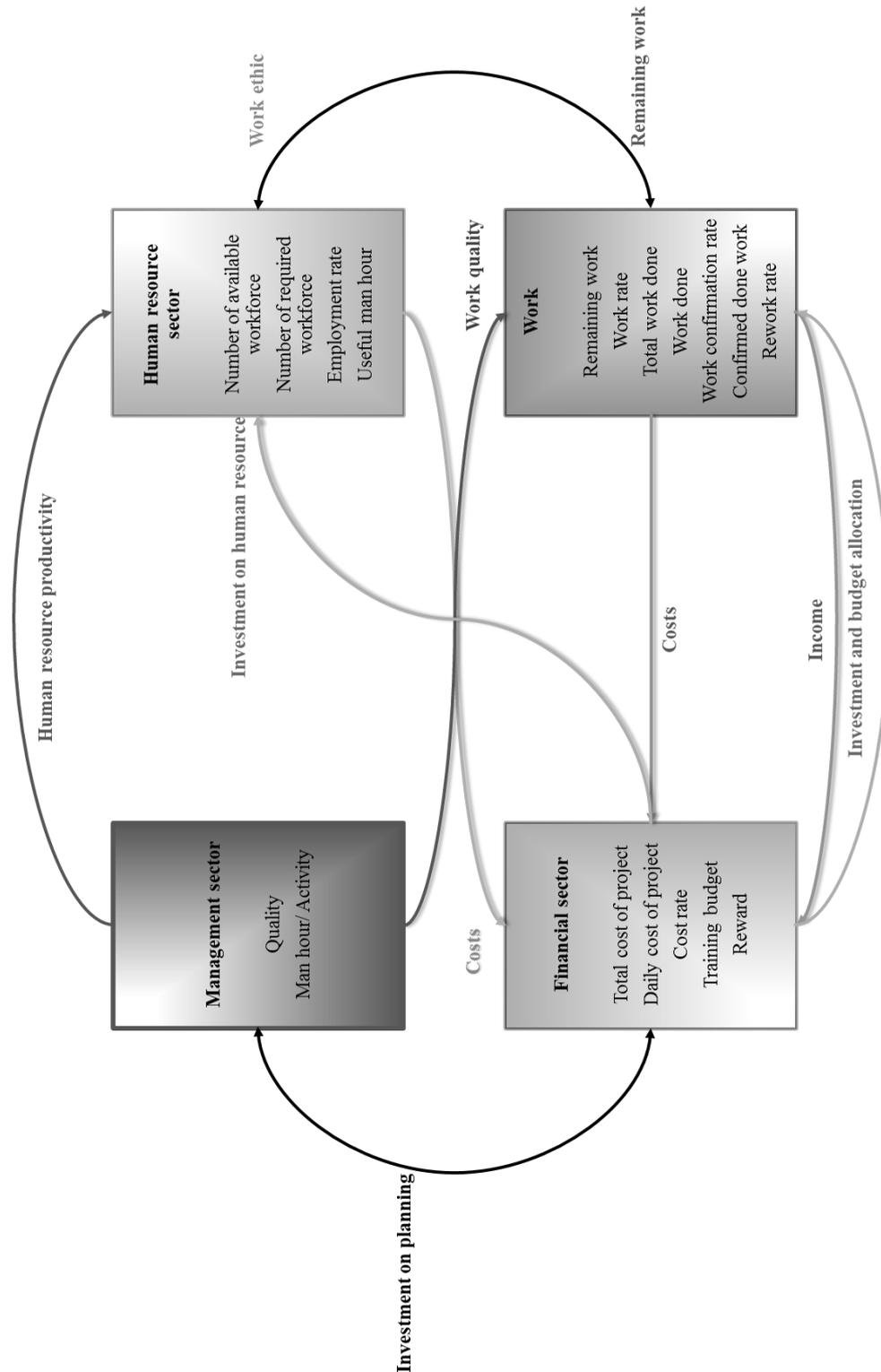
Figure 5 shows the subsystem diagram of the system under study. The work subsystem operates by carrying out activities related to work ethic, the quality of work, and the amount of investment and allocation of funds, and provides the remainder of the work to the human resources subsystem. On the other hand, it provides the cost and income information to the financial subsystem. The human resources subsystem also delivers cost information to the financial subsystem, and it also plays an essential role in the prosperity of work, human resources and management subsystems by investing in these three subsystems.

The quality of the project, which is influenced by the percentage of work ethic (which is itself a function of normal work ethic, financial and language incentives, and knowledge maturity) and the fatigue caused by project progress variances, is the amount that the project's existing profiles meet its needs. Project quality management includes all stages and sections of the project including the initial definition of the project through project processes, project team management, delivery and project closure.

### THE CAUSAL LOOPS DIAGRAM

Figure 6 illustrates the causal loops of the study system. One of the influential factors in drawing up the causal loops is their simplicity and comprehensiveness. Therefore, only the main causal loops are shown in the following figure, and further details will be given in the stock and flow diagram. In the following, we explain the causal loops of the system that generate the system's main behavior.

As shown in Figure 7, the first loop is called the "Percentage of Normal Work Ethic" loop. As the percentage of variance in the project increases, work ethic increases depending on the cost of the allocated training budget, the project diversion rate and the percentage of rework, as well as financial and language incentives [35]. This increase will increase the quality factor and the effective man hours of the project and will increase the work rate. This will increase the work done. On the other hand, reducing the variance reduces the training budget, which means that there is no need to allocate training budget uniformly throughout the project. So, it can be said that the increase in costs is temporary, and by strengthening work ethic, we will eventually see a reduction in costs on one side, and an increase in the progress of the project, which will result in a reduction in the level of rework.



**Figure 5.** Subsystems diagram.

As shown in Figure 8, the second loop is called the “percentage of variance” loop. By reducing the percentage of actual progress, influenced by the approved work and the initial remaining work, the percentage of the variance that is the index of project variance from the scheduled plan, increases relative to the percentage of program progress. Consequently, the level of work-related fatigue increases as the project takes longer [36], which reduces the quality of work.

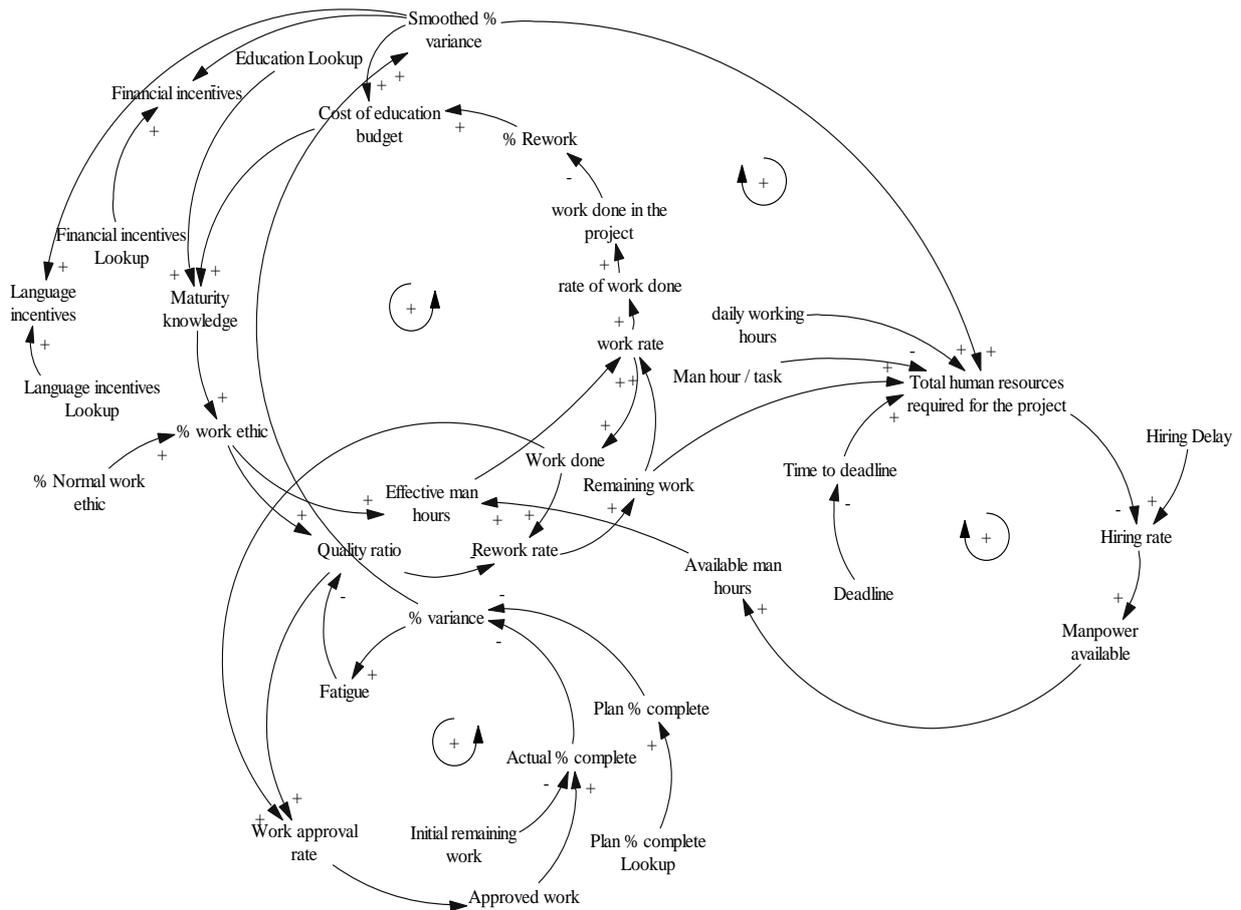


Figure 6. Causal loops of project management rework system.

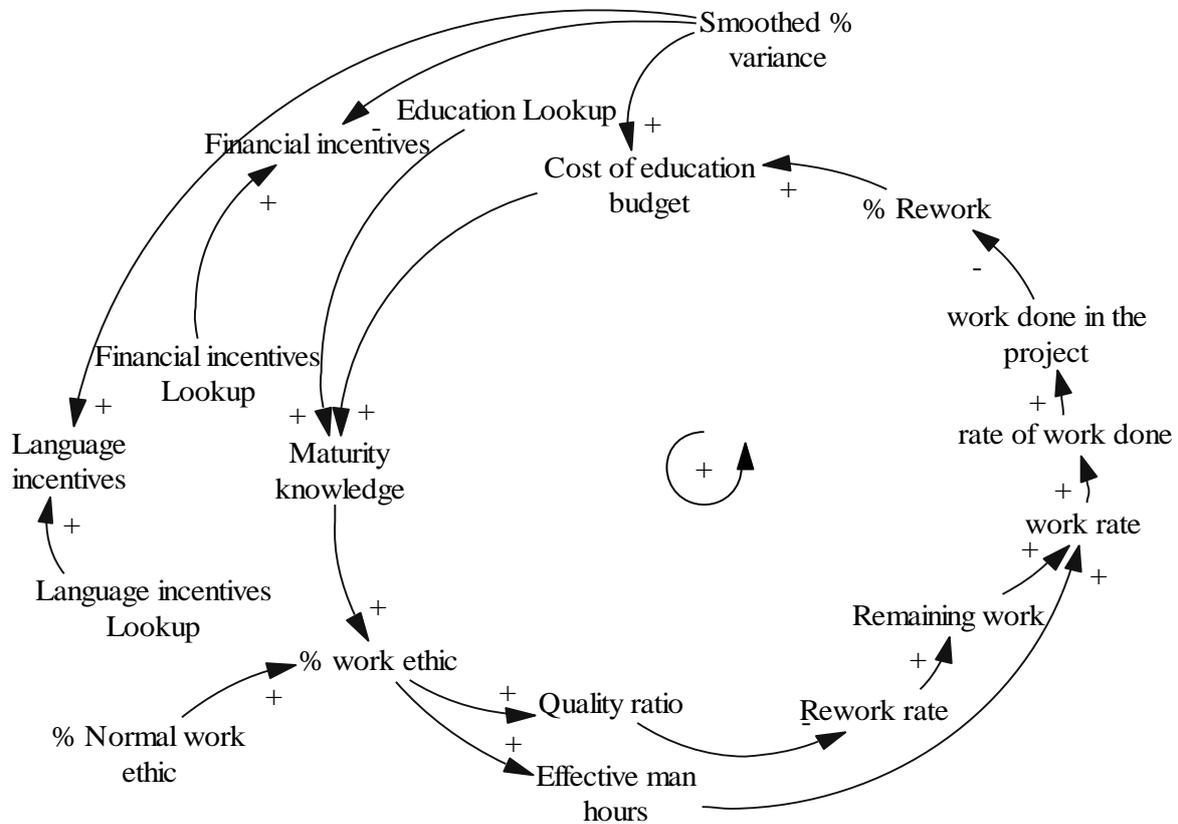
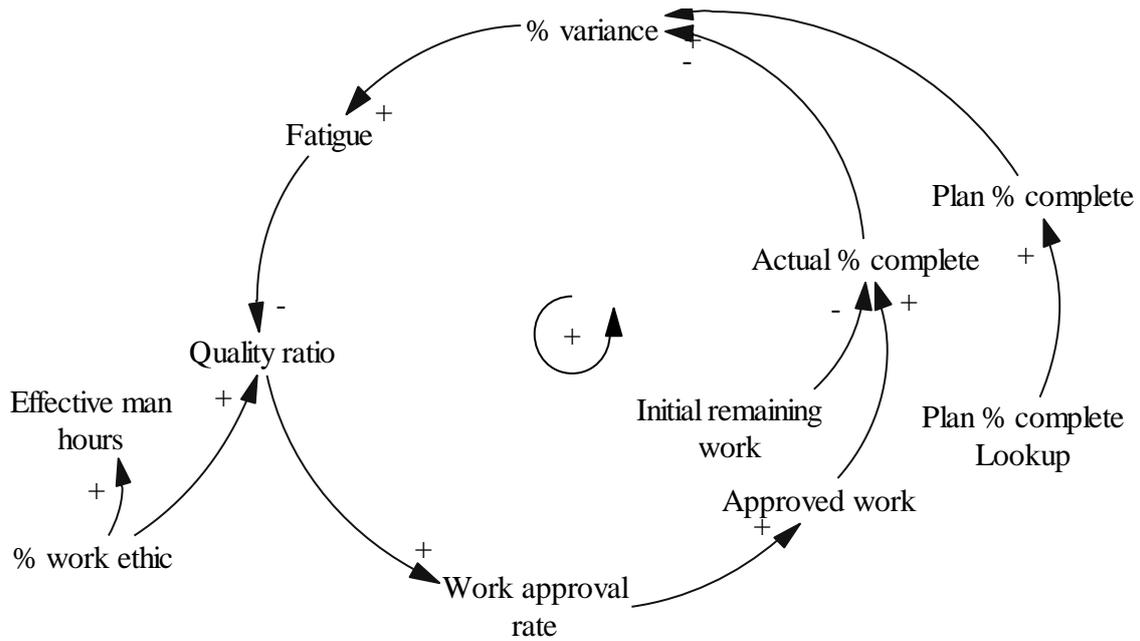


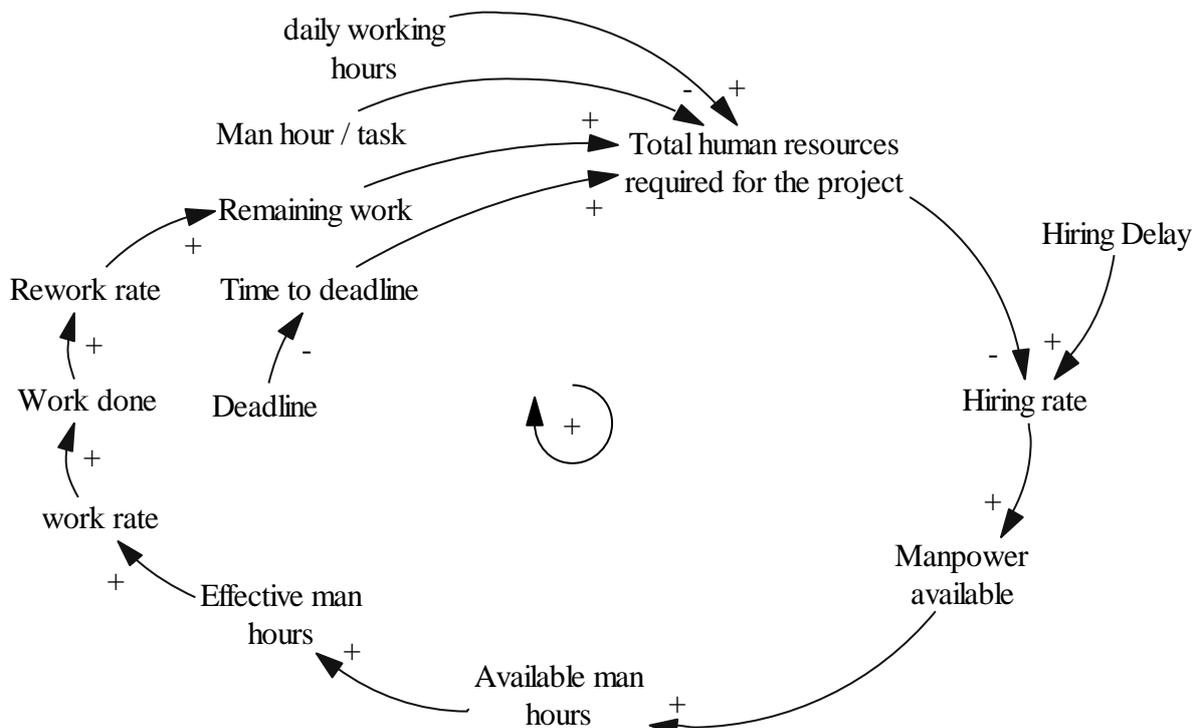
Figure 7. Causal loops – percentage of normal work ethic.



**Figure 8.** Causal loops – percentage of variance.

As shown in Figure 9, the third loop is called “manpower hiring” loop. As the project completion time increases relative to the contract deadline, actual progress is reduced and the project variance increases. In such a situation, there are many remaining work in the project, which necessitates the hiring of the required manpower, while taking into account the hiring time limit to compensate for the time and progress of the project.

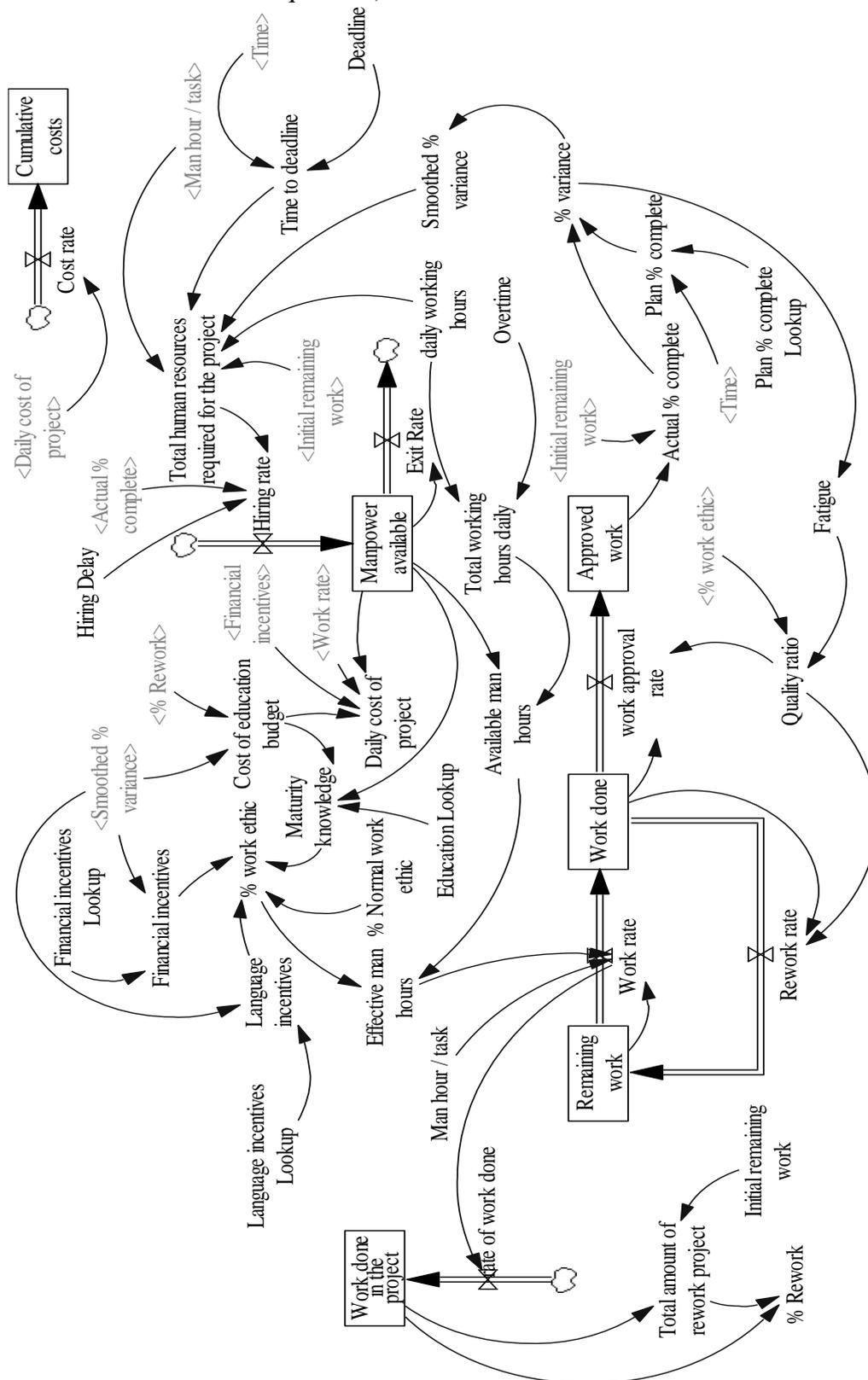
The next section discusses the assumptions that have been used in modeling. The main reason for the limitations is the lack of quantitative information. Therefore, in some cases, it is tried to use appropriate and close approximations using the organization’s expertise in the case study body.



**Figure 9.** Causal loops – manpower hiring.

**STOCK AND FLOW DIAGRAM**

Figure 10 shows the stock and flow diagram of the overall results of simulation of the project management rework System Dynamics model. This model consists of 6 level variables, 6 rate variables and 35 auxiliary variables (which include coefficients, exogenous variables, and correction variables of units of equations).



**Figure 10.** Overall results of simulation.

## RATES

### Work Rate

As shown in Figure 11, factors affecting the determination of work rate are remaining work, effective man hour, and man hour/activity.

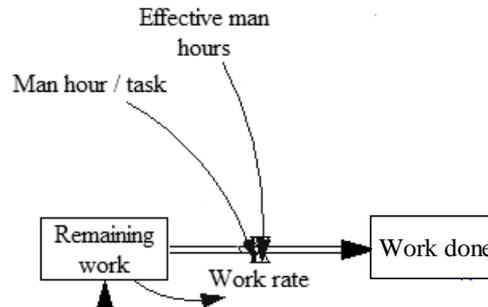


Figure 11. Stock and flow diagram – work rate.

### Approved Work Rate

As shown in Figure 12, approved work rate is obtained by multiplying quality ratio by work done.

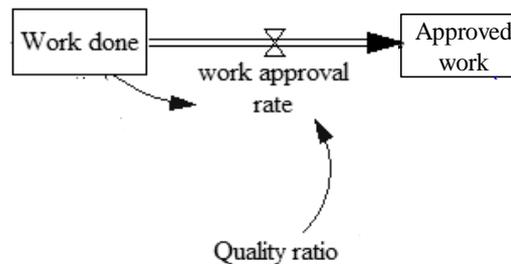


Figure 12. Stock and flow diagram – approved work rate.

### Rework Rate

As shown in Figure 13, rework rate is obtained by multiplying quality ratio by work done.

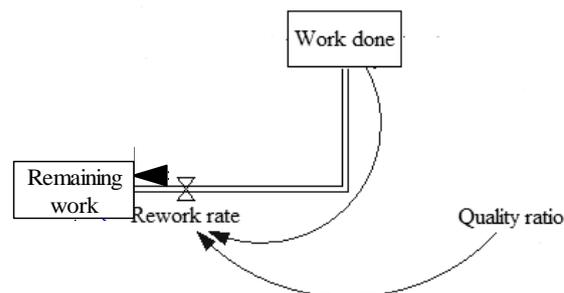


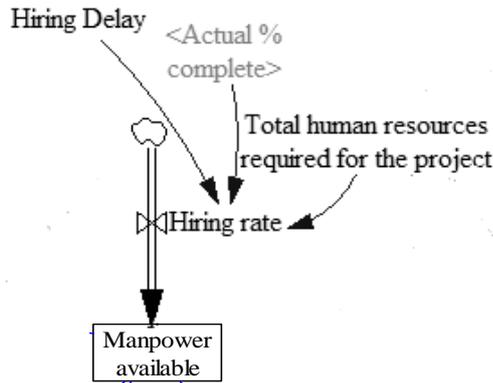
Figure 13. Stock and flow diagram – rework rate.

### Hiring Rate

As shown in Figure 14, hiring rate is affected by actual progress percentage, total manpower required, and hiring delay. Therefore, considering hiring delay, if the actual progress percentage is 50 %, 70 %, 80 %, and 90 %, then 2; 1,5; 1 and 0,5 people would be hired, respectively.

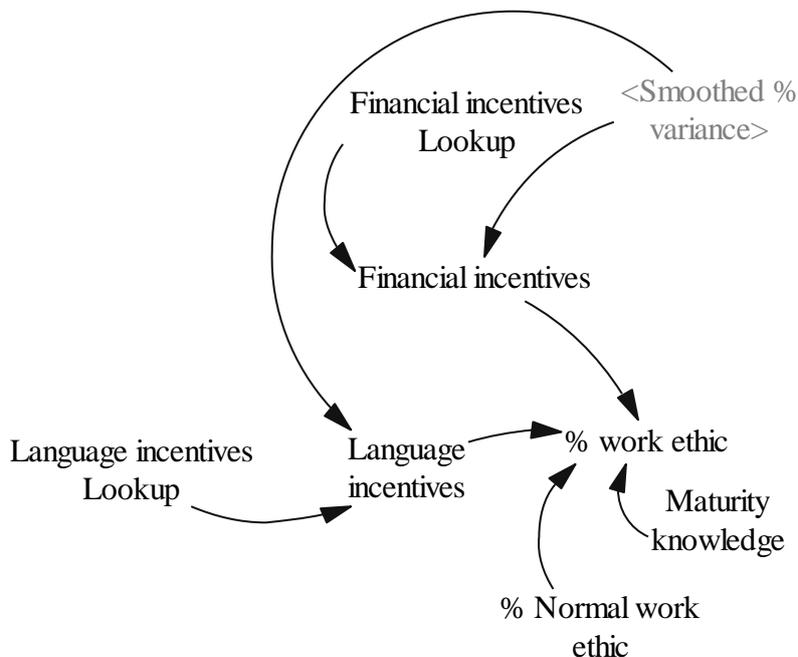
### Percentage Of Work Ethic

According to Figure 15, the percentage of work ethic is influenced by the constant coefficient of normal work ethic and three parameters of knowledge maturity, financial incentives and



**Figure 14.** Stock and flow diagram – rework rate.

language incentives. All of the three parameters are qualitative parameters, which is why they have been converted into quantitative variables using the Fuzzy Inference System in MATLAB software and the mamdani type. First, the input and output variables and their range were determined (Except for the financial incentive input because of the punitive factor; if the percentage of rework that is in the range of -1 to 1 is high, other factors are defined in the range of 0 to 1).



**Figure 15.** Stock and flow diagram – percentage of work ethic.

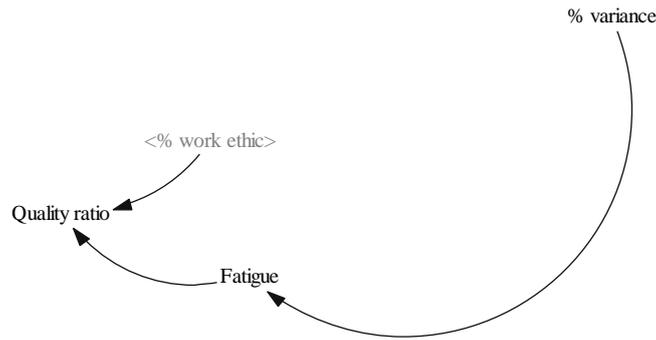
**Quality Ratio**

As shown in Figure 16, work quality ratio is affected by fatigue caused by project variance and work ethic. These two parameters are qualitative and have been converted into quantitative type with the help of fuzzy inference system.

**MODEL VALIDATION**

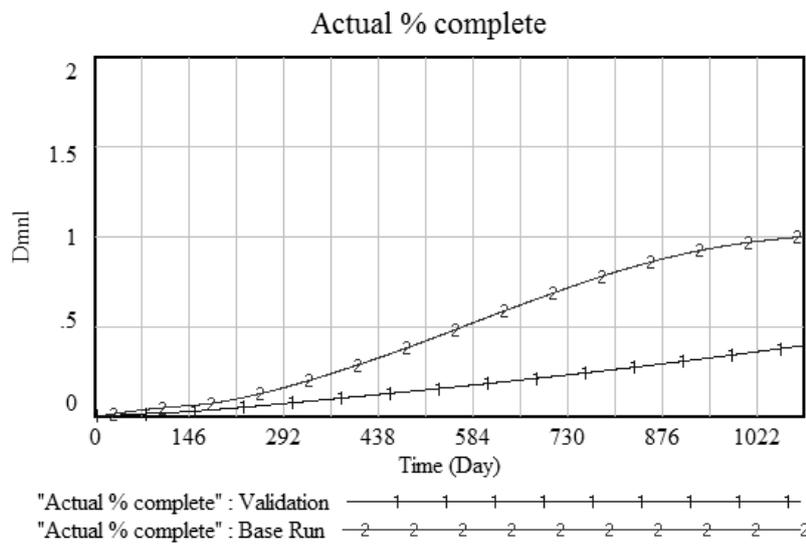
In this model, the adequacy of the boundaries was checked through expert opinion.

Regarding the meetings held with experts in the development of the model, the model is clearly compatible with what is happening in the real world in terms of the evaluation of the structure and the parameters. There is also compatibility with similar models in the literature.



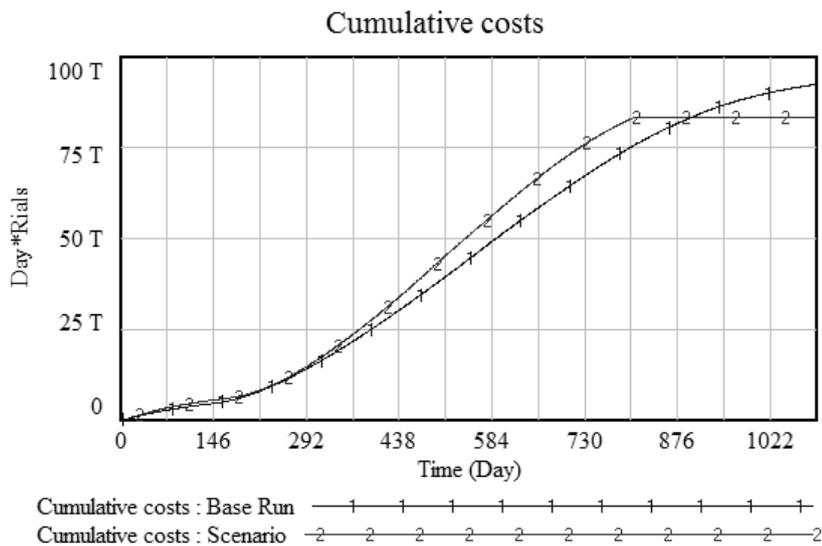
**Figure 16.** Stock and flow diagram – percentage of work ethic.

In the end-test, as shown in Figure 17, if the daily working hour parameter suddenly changes from 6 to .5 hours, the percentage of project progress after the end of 3 years will fall from 100 % to 39 %.



**Figure 17.** Validation – end-test – progress percentage.

In the study, there were no definite historical data, but in order to reproduce the behavior using simulated values, as shown in Figure 18, the model behavior had a perfect match with that mentioned in reference mode (Fig. 4).

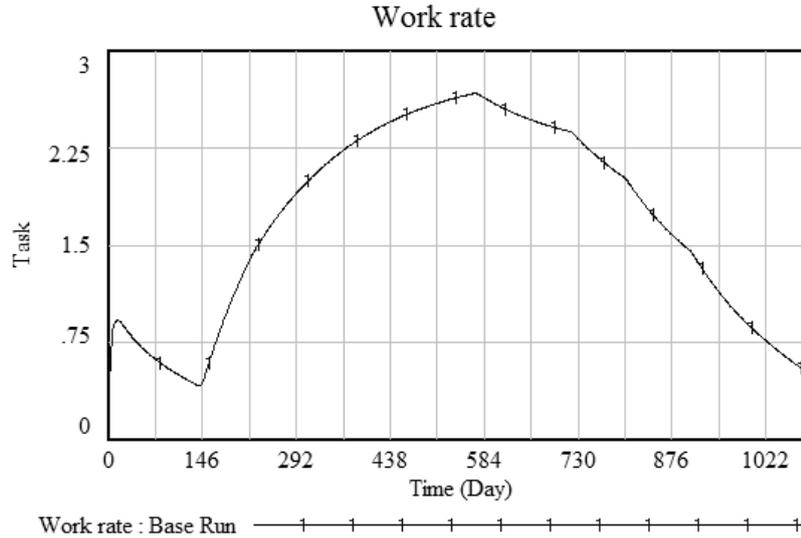


**Figure 18.** Validation – behavior reproduction test – costs.

## SIMULATION RESULTS

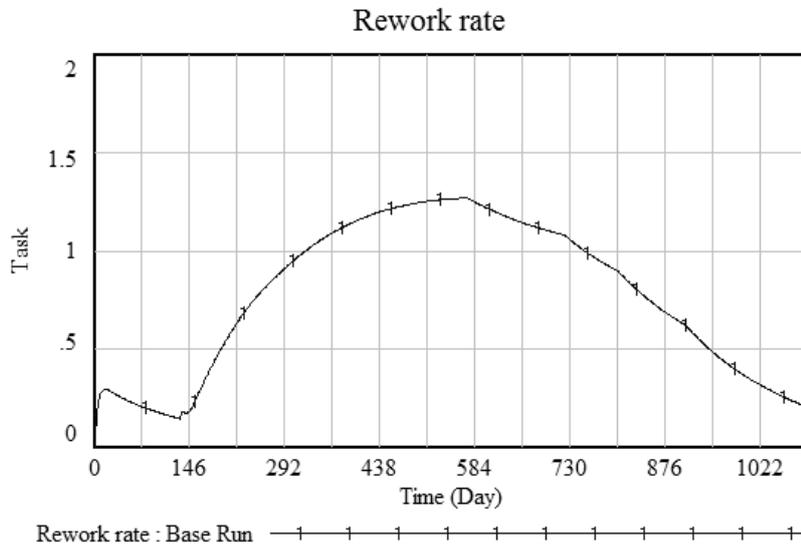
### SIMULATION RESULTS IN THE BASE MODE

Figure 19 shows the work rate behavior. According to this figure, the model has been able to produce work rate behavior. On the peak, 2,67 works are done per working day.



**Figure 19.** simulation results – in the base mode – work rate.

Figure 20 shows the rework rate. According to this figure, on the peak, 1,67 reworks are done per working day.



**Figure 20.** simulation results – in the base mode – rework rate.

Figure 21 shows hiring rate in the base mode. Hiring rate varies depending on the actual progress rate that is itself affected by project variance and hiring delay in different time periods.

### SIMULATION RESULTS UNDER IMPROVEMENT SCENARIO

The findings showed that, with special attention to work ethic as can be seen in Figure 22, the work rate increases. This means that effective work force performs more activities during daily working hours, and the maximum number of activities performed from 2,67 in the base mode increases to 3,17 under the improvement scenario.

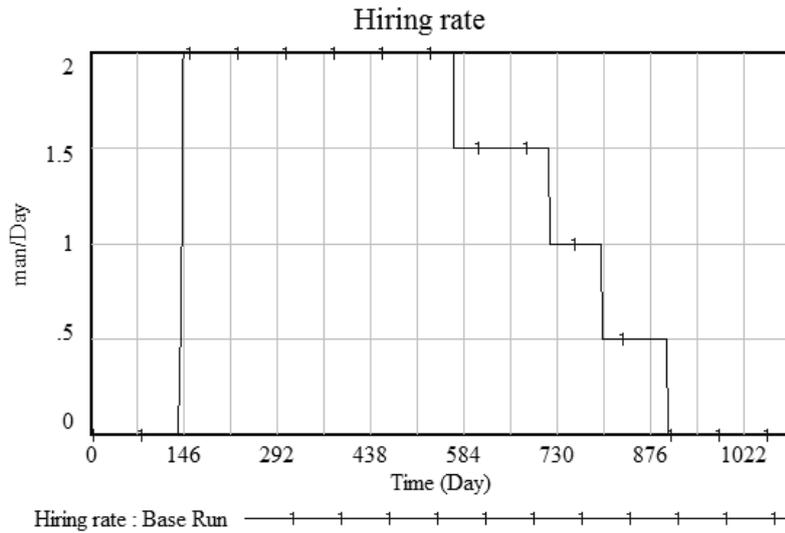


Figure 21. simulation results – in the base mode – hiring rate.

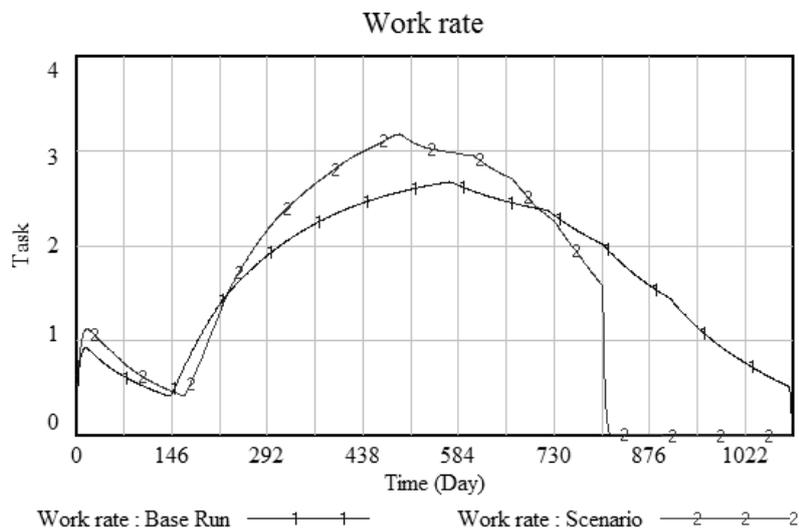


Figure 22. Simulation results – in the base mode and improvement scenario – work rate.

Figure 23 shows that except for a short period, rework rate has decreased during the project.

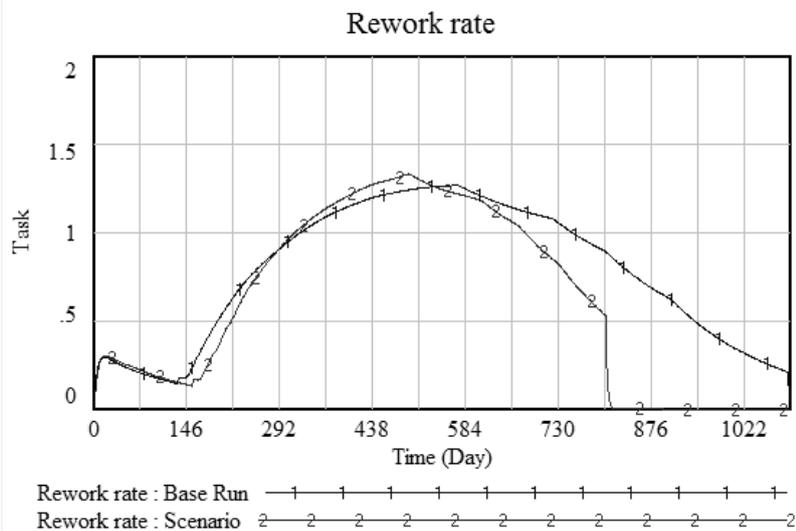
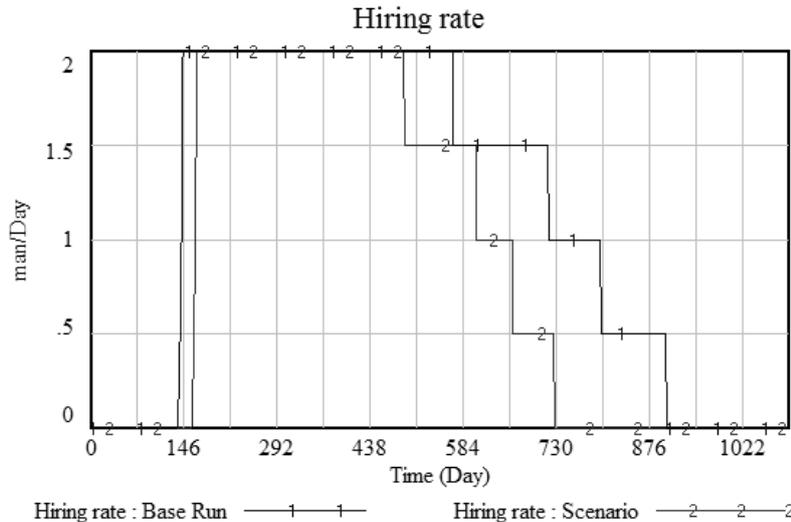


Figure 23. Simulation results – in the base mode and improvement scenario – rework rate.

As shown in Figure 24, hiring rate has significantly decreased in the simulation under improvement scenario compared to the base mode.



**Figure 24.** Simulation results – in the base mode and improvement scenario – hiring rate.

## DISCUSSION

Regarding the model investigation and information analysis, it was found that the impact of the work ethic culture on rework in construction projects cannot be ignored. Managers of large projects can better manage project costs and time by allocating budgets to training and financial and language incentives. It seems that this solution has the ability to be generalized to other projects in non-construction fields after the need-assessment and identification of the problem, and the concept of this research can be used to achieve desirable results in other sciences, including the humanities and engineering. The dynamics presented in this study through expert opinion were selected as items and main variables.

Based on the causal loops that their impact mechanism was described, it can be concluded that if the percentage of project variance increases, work ethic increases by increasing the training budget depending on the degree of project variance and the percentage of rework, as well as financial and language incentives. With this solution, the quality of the desired work, which is one of the project management strategies, is realized. Also, the causal loops emphasize that fatigue due to the prolongation of the project reduces the quality of work, so in order to cope with this problem, we should seek a solution to reduce the time variance in the project. In this study, the suggested strategy considering the dynamics and existing loops is to strengthen work ethic. Hiring manpower was also suggested as a solution to compensate for delays in the time table.

The results of the study in the base mode indicated that despite the financial rewards, language incentives and costs for training and upgrading the personnel knowledge, the maximum level of work ethic was 65 % during the implementation of the project, but after simulation, if the budget is allocated to training and financial incentives, it can also be expected to maximize the growth of work ethic by 86 %. In addition, the total cost in the improvement scenario is reduced by 10 % compared to the base mode, and the 730-day project (2-year-olds) is scheduled to reach 100 % completion over the course of 823 days, while this number is 1095 days in the base mode (3 years). This means that the cost of the project, which is affected by the daily cost of the project, is maximized with the application of work ethic policy. However, because of the completion of the project in a shorter time period, it actually leads to a significant decrease, which confirms the dynamic hypothesis of the research.

## CONCLUSION

The dynamics of the construction industry is one of the most important factors in the development of economic activities. Therefore, this industry is very important in economic development. Due to this importance, the research was carried out on the impact of work ethic on the degree of rework in the construction industry. In this study, it was investigated to see whether increasing the cost of training and incentives and, consequently, motivating people to strengthen work ethic could improve the cost performance and project time.

The results of the research showed that despite the financial rewards, language incentives and costs for training and upgrading the personnel knowledge, a significant level of work ethic cannot be considered, but after allocating budget to training and financial incentives, it can also be expected to maximize the growth of work ethic. In addition, the total cost is reduced and the project ends in a shorter period. The present research can be the basis for planning human resources in the field of project control and identifying the major human resources strategies in the field of human resource management in projects because construction industry planning is known as a complex system with high effective factors. The limitation of the lack of quantitative information prevented further development of some parts of the model. Therefore, in some cases, it was tried to use appropriate and close approximations using the organizational expertise in the case study body.

The purpose of this article was to study the effect of work ethic culture on rework in construction projects through modeling and analyzing information using the system dynamics approach.

In the current study, the relations of the fuzzy inference system were linear and it is suggested to consider them as non-linear in future investigations. Moreover, in this study, just one project was investigated and it's better to study more projects in future studies.

In this research, only rework in construction projects were considered, it is suggested that the research should be carried out on projects where the role of manpower is more important in terms of precision, such as research projects, handicrafts, etc.

Furthermore, in this research, the dynamics of the effect of education and financial and language incentives on work ethic was investigated. It is suggested to investigate the dynamics of other factors affecting work ethic such as paying attention to individual characteristics, the nature and type of occupation, employee evaluation, the strengthening of faith and piety in the community and the economic supply of the workforce due to cultural differences and differences in education levels, and the same feedback.

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# STUDENT EMPLOYMENT: CHARACTERISTICS AND EFFECTS OF ITS USE IN CROATIA

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## ABSTRACT

The article deals with student term-time employment in Croatia, causes of its growing prevalence, its patterns and legal regulation, and finally its effects on the higher education system and labour market. Overview of the theories on combining work and study singled out few relevant factors determining motivations of students for engaging in term-time employment and employment's different academic and professional outcomes, mainly related to the massification of higher education phenomenon (higher number of students and their greater diversity, youth unemployment, and questionable college degree relevance). Although conducted on non-systematic data, gathered from previous research of student population in Croatia and EUROSTUDENT international research on the quality of student life, analysis carried out in this article showed the occurrence of higher education massification and its influence on student employment, especially in the fields of social sciences and humanities. Croatian students' motivations for term-time employment are mainly a wish to improve their living standard and a need for work experience, while their average workload is of low to medium intensity, usually on jobs not at all related to their future profession. Apart from presenting the practice of student work use, this article also gives an overview of its legal regulation in Croatia, and examples of its misuse, i.e., negative implications it may have on student and regular workers.

## KEYWORDS

student term-time employment, student work regulation and misuse, massification of higher education, labour market, EUROSTUDENT

## CLASSIFICATION

JEL: I23, J21, J22, J23, J24, J41

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## **INTRODUCTION**

Over the past two decades a rapid expansion of higher education student numbers has been evident [1], and given this so called “massification” of higher education, employment during studies has become a common phenomenon worldwide [2, 3].

Most of the publications dealing with student employment focus on students’ academic performance [4, 5] and professional outcomes [5-7] in the context of analysing their employment's influence on the mentioned. Apart from that, studies which mention or analyse student work do so also in the context of students’ economic and social backgrounds, their equality and possibilities [8].

As it is shown in the works of Roshchin and Rudakov and Neyt et al. [5, 8], those studies are generally based on several key theoretical concepts, such as the transformation from an elite to mass higher education and the change of profile of higher education students [9], the job market signalling theory [10], the human capital theory [11], the theory of the allocation of time [12], and the primary orientation theory [7].

Available literature on student work in Croatia is very scarce and falls mostly in the domains of diversity of higher education students and inequality of life chances research [13-15], with student employment itself, and its potential impact on student success or wellbeing not being the subject of any, let alone systematic and consistent analysis.

The goal of this article is to give a short review of the available literature explaining student employment decisions and its intensity, and to try to connect existing theories to the practice of student employment in Croatia. This will be done firstly by presenting Croatia’s legal framework of student work and available data on its prevalence among student population, and afterwards by summarising the main findings in relation to the key elements of student employment motives and effects set out in the theoretical review. Another goal of the article is to detect and present the problems surrounding this kind of employment, as well as to propose ways for its better implementation and utilisation.

## **THEORETICAL FRAMEWORK: INCIDENCE AND IMPACT OF TERM-TIME EMPLOYMENT**

A global increase in student employment can be explained by the already mentioned massification of higher education which entails a transition from the notion that higher education is something reserved to elites to a mass higher education and the influx of different and more numerous social groups. Apart from the increasingly heterogeneous and numerous student population, massification potentially leads to a “decrease in the quality of education, an increase in government expenditure on education, a disproportionate structural labour market and youth unemployment” [8, 9].

Those structural changes in higher education cause an over-supply of graduates, especially in certain study fields, and an increasingly competitive graduate jobs market [1], where higher education certificates, according to Roshchin and Rudakov, lose their significance, while work experience is becoming another important signal of high productivity [8]. This way term-time employment is becoming “a way for students to gain additional transferable skills (i.e. additional investment in human capital) and distinguish themselves from the ‘mass’ [1]. Many authors mention work experience, paired with college qualifications, as a ‘signal’ of graduate’s quality that can lead to easier attainment of a suitable job [1, 10]. However, graduate employers are still more attracted by graduates’ success in their studies and their

degree work experience, than by graduates' term-time work experience and volunteer work [1]. That being said, students undertaking a full-time or higher-intensity job (11 hours per week or more) are more likely to be employed after graduating, which can be explained with the potentially positive impact of the newly acquired skills (human capital theory) or of the 'signal' of being able to balance significant workload with studying (signalling theory) [1].

Structural changes are also visible on the job market, where a greater deal of combining work and education opportunities occurred due to the development of nonstandard types of employment suitable for students, such as part-time work, flexible working hours employment, remote work, and outsourcing or freelancing possibilities [3, 8].

Perhaps the most prominent focus of student employment research lays in its impact on academic performance of students. Most of the studies or, according to an overview by Neyt et al., exactly 31 out of 48, identified the negative impact of the mentioned, confirming the theory of the allocation of time and the primary orientation theory, also called the zero-Sum theory [5], which to some extent contradicts the human capital theory. Zero-sum theory simply argues that time spent working crowds out the one spent on academic activities (studying, doing homework and attending classes), which consequently worsens academic performance [5, 6, 16].

However, those studies have also shown that the impact of term-time work on academic performance is dependent on its intensity, i.e. weekly working hours. Taking the weekly workload of students into consideration, studies have shown that low or moderate employment intensity have positive effects on students' academic achievements (or, at least, don't impact it negatively) but that at a certain point this effect becomes negative [4, 5, 16, 17].

The only problem with that, as it is in the case of student work effect on graduates' employment, is the definition of the threshold value of high work intensity. While some authors define it as more than 24 or 25 hours per week [4, 5, 8, 16, 17], other thresholds are considerably lower, and range from working more than 8 or 12 hours per week [5].

In regard to student motivations to engage in employment during studies, they are firstly and most obviously related to the financing of their education, especially considering the rising involvement of students from lower-income families in tertiary education or the ones with the lack of family support [16, 17]. Secondly, and, for a great deal of students, the only reason for combining work and education, is paying for social and leisure activities or luxuries [1, 3, 5]. Gaining work experience has proven itself to be less of a frequent reason for engaging in employment, particularly if career related, and, while the majority of students report being employed during studies, few of them perceive it as a form of human capital investment in their future professional development [1].

It is important to emphasise that some authors mention the differences between "advanced economies" and transitional ones regarding the relevance of term-time employment's and college certification's 'signal' on the job market, and consequently differences in student employment motivations. As already mentioned, in advanced economies, academic excellence is still valuable for employers and work experience is not so important, so financial or leisure motivation prevails among students. On the other hand, transitional economies have been more affected by the negative consequences of the higher education massification, and in turns academic credits lost their significance as relevant job market signals. In those economies, according to the authors, work experience gains in importance for employers and takes first place in students' motivation for engaging in employment [8].

## **YOUTH IN CROATIA – HIGHER EDUCATION AND LABOUR MARKET POSITION**

Although the general unemployment rate in Croatia is, and has been, the most prominent issue of Croatian economy, young people are those particularly affected by it and those who are rapidly becoming the most vulnerable group on the labour market. In 2016 the youth unemployment rate in Croatia was one of the highest in the European Union and amounting to 31,3 %. For the comparison, 2016 average youth unemployment rate in the EU in was 18,7 [18]. Although lower, the unemployment rate of young people with tertiary education in Croatia is fairly high and, amounting to 28,7 % in 2016, significantly higher than the 13,8 % EU average rate [18].

According to a 2013 study of youth perspective in the period of crisis, two fifths of employed young people do not work in the profession they were educated for [19; p.67], and although those with higher education have a better chance of getting a job in their profession, they don't seem to be confident in finding a job at all after the graduation, especially those living in cities and older students [19; p.55].

Regardless of that, high youth unemployment rates, especially among the less educated, are a great incentive for college enrolment. As Babić et al. claim, after completing secondary education Croatian youth is not faced with the dilemma of participating in the labour market or attending college, but the dilemma of attending college or being unemployed for a long period of time [20; p.131]. This is connected to youth professional aspirations, which are mostly extrinsically oriented and include higher salary, job security and existence assurance, rather than those intrinsically oriented, such as performing socially relevant work or employment within gained profession [19; p.67].

The massification of higher education is also very present in Croatia - its student population rose by 82 % in the period between 1990 and 2005 [20]. This information alone wouldn't be as problematic, if that expansion wasn't mainly concentrated in the social sciences and humanities area, non-university courses and among part-time students, i.e. mainly student who are paying tuition fees. Since 2000, subsequently, the proportion of private tuition fees exceeded 20 % of the total tertiary education cost, and the publicly financed ones decreased [20; p.125].

According to the data of Ministry of Science and Education, about 65 000 full-time students annually do not have to pay tuition fees, almost 60 000 of them pay a certain amount, and 39 724 of part-time students pay its full amount [21]. In other words, 60 % of students pay a tuition fee, which represents a big increase compared to 1993/1994 when the share of those student amounted 12 % [15].

Since the scholarship fund is not excessively funded, with less than 7 000 scholarships being awarded by the state and universities [21], a great deal of students depend on their parents' financial support, as well as student or regular work.

## **LEGAL FRAMEWORK OF STUDENT EMPLOYMENT IN CROATIA**

Student employment in Croatia is legally regulated only in the case of full-time students' work, and that is done primarily through the Scientific Activity and Higher Education Act, and the Regulation on intermediaries for employment of full-time students, but also by the Pension Insurance Act and the Contributions Act [22]. According to these acts full-time students have the right of employment via student service centres [23; Art.88] which are in charge of keeping a record of its members (full-time students), appropriate processing of the

student job market, calculation and collection of student earnings, required contribution and the mediation fee, and finally paying student earnings free of charge [24; Art.2].

Student employment regulated in this way does not undergo the provisions of the Labour act and represents a special form of work, one not pertaining the employment relationship. The performing of a particular job by a student implies the use of contract for work (service)<sup>1</sup>, or in this case called student contract for work [24; Art.5]. As it will be made clear later, herein lies one of the greatest problems of the student work arrangement, since it has all of the characteristics of an employment relationship, but is not classified as such. The only difference between student's and regular employment is the duration of it, since student work is usually temporary and of short duration [25; p.11]. In this way, student employment is sort of an exception which is allowed because its current arrangement usually favours students, their parents, student centres and employers [22], as students are their parents' tax relief, a source of income to student centres and cheap workforce for employers.

Student work regulation and its tax relief system in Croatia can be linked to the one of casual or provisional work in other countries [26]. By employing students, employers don't have to pay taxes and contributions, only particular and reduced pension and health insurance contributions, and 12 % provision for student service centres. This way, student work contract implies 17,5 % expenditure on the gross amount of the paycheck [27], while, on average, employment contract the same expenditure amounts to 41 % [26; p.100].

The minimum wage of student work is defined in accordance to student centres' acts and price lists, and it currently, although depending on the type of performed job, amounts to around 15 HRK (2,02 EUR) per hour. According to that, minimum monthly net earnings of students is 2 640 HRK (356,14 EUR), which is similar to the minimum net wage of Croatia [21].

Currently there is no restriction on the maximum weekly working hours, nor is there a maximum annual earnings set for that kind of working arrangement, but there are two limits, according to the Regulation in income tax, which regulate favourable tax provisions of student work. The first limit addresses the tax relief clause and proscribes that students cease being a tax relief for their parents when they earn more than 15 000 HRK (2 023,55 EUR) in a year [28; Art.6]. Another limit deals with non-payment of income tax, which ceases when students exceed an annual income of 60 600 HRK (8 175,14 EUR) working on student contract for work [23; Art.55].

In November 2017 a proposal for the new Student work act has been published, with its main novelties being an introduction of part-time students working via student contracts, and of a general minimum student hourly wage which would be defined in accordance to national minimum wage [21]. The introduction of this law has led to numerous allegations by trade unions, experts and non-governmental organizations, mainly because of the introduction of the two mentioned clauses, but also because of, in their opinion, too lenient penalties for the student contract misuse. It is important to note that the proposed law is not currently being enforced.

## **INCIDENCE AND PREVALENCE OF STUDENT EMPLOYMENT IN CROATIA**

As already mentioned, there are no systematic and longitudinal data on the prevalence of student employment in Croatia, at least not government data made accessible to the public, such as national bureau of statistics, employment service or relevant ministries. But, there are isolated information and small research outputs, gathering which can provide a general insight into the extent of student employment and its key features. This part of the article will therefore firstly present data on the extent of student employment, then gathered insights on

the type of work students are mainly performing, and finally present available data on the character of their employment, including motivation for it, its duration and connectedness with students' future professions.

According to the Ministry of Science and Education data, in 2014 the number of employed full time students amounted to 75 435, meaning that almost 65 % of regular students worked at least once on student contract for work, making a profit of 965 673 398 HRK (129 770 105,24 EUR) [26; p.100], which is a 12 801,40 HRK (1 720,29 EUR) average yearly profit per student. In 2016 those numbers rose and now 84 517 regular students worked on student contracts, making a 1145 014 967,55 HRK (153 870 566,54 EUR) profit and a personal per student profit of 13 547,75 HRK (1820,59 EUR) yearly [21]. In 2016 over 68 % of full-time students worked for a certain period of time, which indicates the increase in, not just the entire student population, but also in the share of working students. With an average hourly salary of 20 HRK (3,37 EUR) student working on student contract works 677 hours, or 17 weeks in a full-time employment of 40 hour per week (8 hours per day). On a yearly basis, this means that an average student spends 4 months and more working full-time [29]. It should be noted again that the above presented data applies only on full-time students who are able to use student work contracts, not on part-time students, particularly 39 724 of them in 2016 [21]. The number of students in general, and thus the share of working students in Croatia is higher.

A student job listings analysis conducted by Croatian Youth Network in September and October 2017 on 160 listings showed that student work is sought-after in many different sectors, but the ones in which it is the most prominent are phone sales, customer support, trade and secretarial positions [29]. Research on employers attitudes and opinions conducted in 2014 and 2015 on 13 121 employers also mentions some of the sectors where student work is widespread, which include accommodation and food service activities, with one study showing that employers of that sector hire student most frequently with a share of 26,4 % [30; p.65]. According to the study based on 16 semi-structured interviews with representatives of Croatian social partners in selected sectors and relevant experts in 2015, big retail centres are also common student employers. There students often have low responsibility assignments and sometimes even work on projects funded by third parties, not the retail companies where they perform the work [31; p.70]. The recent economic crisis impact has led to an increase in use of student contracts for work in many sectors, primarily so in the sector of retail [31; p.85]. Apart from the crisis, other factors can also favour the rise or the fall in the student work use, as for instance did the introduction of the Fiscal system act in the accommodation and food service sector, making informal economy activities more difficult to maintain [31; p.43], so students, seen as a cheap work force, became practical as a black market workers' replacement.

Since the above mentioned jobs are not particularly concrete and usually imply hiring secondary school graduates on a regular full-time employment contract, employers often seek students with working experience in the required field who are willing to work 40 hours per week [29; p.4] and for a longer period of time, very often for 6 months or a year [22, 29]. Some student job listings require master level students, most often those with technical or business courses, because of their usable knowledge [29] which is a great way for a student to acquire practical knowledge and valuable professional skills, especially given the rather poor use of student practice in general. On the other hand, some employers hire exclusively senior undergraduates (cro. *Apsolvent*<sup>2</sup>) because they need a student to work full-time [29].

Although conducted on the whole student population (not only on full-time students able to work on student contracts), data of EUROSTUDENT international research on the quality of student life, will provide some of the insights on student employment patterns in Croatia for the purposes of this article, especially since the majority of respondents (74,4 %) is enrolled in full-time studies [32]. Considering the existing proposal of making the institution of student work available to all students, this survey's results can be perceived as potential indicators of the future state of some student work aspects in Croatia. EUROSTUDENT survey in Croatia was conducted via online questionnaire on 2 551 students (2 % response rate) in 2013 and 2014. Since all students have been invited to participate in the survey [32], meaning that no sampling method was used during data collection or its preparation for analysis, the below presented survey results should be taken with caution.

As higher education in Croatia is often considered a “full-time” job, it should not come as a surprise that almost half of the respondents (47,5 %) found that working “because I have free time to spend” did not at all apply to their motivations. In counterpart, their motivation to work was mostly based on either funding themselves while studying, or improving their living standard, with 51 % of respondents saying the former option totally applies to their situation, and 41 % totally agreeing with the latter. As expected, socio-economic variables seem to highly moderate students' motivation to work while enrolled in higher education, with 60 % of students without an HE background<sup>3</sup> working mainly to fund themselves (as opposed to 39 % of those with an HE background), and 77 % of students aged 30 or more working to fund themselves (opposed to 37 % of them aged 22 or younger).

Although maintaining or improving their financial status seemed to be the main motivator in students' work, both students living with their parents and those who aren't find their monthly income mainly funded by either family or partners, with at-home students having 66 % of their income funded that way, with their counterparts having 64 % of their income coming from those sources.

Additionally, since, as previously mentioned, student practice, both in and outside of the universities, is often found lacking in the various fields of Croatian higher education, a majority (57 %) of students say that their motivation to work comes totally or mainly from the need to gain some experience in the labour market [32].

Unfortunately, the need to gain some experience in the labour market doesn't always mean students will get experienced in their future professional fields. On the whole sample, more than half of the respondents (56 %) found that their student work was not at all or only slightly related to their studies, with less than a third of them (32 %) having the luck to work in positions which are closely related to it. Although the situation changes slightly on higher levels of education, with 36 % of students enrolled in their master studies working in fields closely related to their profession, and 31 % of bachelor students doing the same, more than a half of all the student working force found themselves working off-jobs in order to either support themselves or improve their living standard. Although non-university students seemed to have an easier time finding work in their area of studies, with 45 % of them working in closely related professions, such findings should be interpreted carefully, since it could very well mean that they enrolled in complementary studies after finding a profession, in order to improve their positions within the organizations already employing them. Finally, although the EUROSTUDENT data is extremely lacking in the available categories (categorizing students by fields into “humanities” and “engineering”), humanities students do

seem to have a much harder time to find profession-related student work, with less than a fifth of them (19 %) working jobs that are closely related to their respective fields [32].

Student respondents, on average, spend less than 10 hours weekly doing paid jobs, with taught studies and personal study time accounting for the rest of their 44 hours per week load. Although indicative, the means of student workload presented in EUROSTUDENT dataset are far from easy to interpret, as the standard deviation on total working hours (including personal study, taught studies and paid jobs) is 19 hours per week, which would have students' load total range from approximately 20 to 60 hours per week, with such a standard deviation growing on master levels of study. There do seem to be some interpretable variations in a few sub-categories, with master students spending, on average, more time doing paid jobs (13 hour per week) than their bachelor counterparts (9 hours per week), although the difference seems to be accounted for by the reduced load of taught studies on the master levels [32].

Altogether, the EUROSTUDENT data indicate that Croatian students finance their studies mainly through their parents' support and engage in employment mostly to improve their standard, which is in line with the findings presented in the theoretical review [8, 16, 17]. Naturally, students coming from the lower-income families and older students do so with greater intensity, since the financial support of their parents is lower than the one of younger students coming from higher-income housings.

In addition to that, a great deal of students' motivation for term-time employment in Croatia is related to their professional aspirations of getting a relevant experience for future degree related work, which can be explained with students' perception of work experience as a valuable signal to potential employers. This goes in line with the job market signalling theory and the human capital theory, and could, again with a great caution, be interpreted as an indication of the college degree losing its relevance as a job market signal – a result of the negative HE massification influence on transitional economy [8], such as Croatia's.

The average Croatian student workload of 10 hours per week falls into the category of “low to medium” work intensity and should, according to the theory of the allocation of time and the primary orientation theory, lead to a greater academic success of students [4, 5, 16, 17], but cause no effect on his/her later degree employability [1]. Considering the potential decreasing value of university degrees, and especially of those in social sciences and humanities (highly competitive ones and least likely to facilitate a study-related student job), this kind of work intensity shouldn't lead to a student's benefit.

## **SHORTCOMINGS OF THE CROATIAN STUDENT EMPLOYMENT SYSTEM**

From the above described legal framework of student work and its patterns of use a few irregularities can be detected. Firstly, student work does not undergo provisions of the Labour act, meaning that student don't have the same rights and privileges as regular workers which, combined with the feature of relative financial affordability of that kind of work for employers, can lead to exploitation of student workers. Another form of legal misuse refers to a large number of hours and a great income realized by such contracts [16; p.103], since there is no prescribed limit on the two. In addition to this, employers often use student contracts for payment of work performed by a nonstudent [26; p.103].

Secondly, as seen in the overview of student job offers, most of the jobs performed by students do not differ from standard full-time jobs performed by regular workers, which entails two problems: one concerning students themselves, and another regular employees. This way students, as a cheap workforce, can easily replace dismissed or unemployed people,

especially the unskilled ones, as can be seen in the time of crisis [31; p.12] or in periods of the prohibition of new employment, such as was, for example, the prohibition in public services and governmental bodies enacted in 2014 [22]. On the other hand, students employed in trade and services sectors can barely gain any relevant professional experience, especially if their study areas are not related in any way to the aforementioned sectors, which is usually the case. The cases when student can profit from their term-time jobs, in a way they would from the student practice, are rare [29], which leads to a conclusion that the student contract for work use in its current form mostly serves the needs of employers.

## **CONCLUSION AND RECOMMENDATIONS**

Linking the gathered data on student (self)financing and employment in Croatia with the findings presented in the theoretical framework lead to a conclusion that the massification of higher education and its effects are very visible, both in terms of rising government expenditure on education and youth unemployment, and in terms of students' main motivations for engaging in employment. The high rate of youth unemployment and the lack of possibilities for employment with secondary education attainment in Croatia lead to a greater inflow of higher education participants. That consequently increased the unemployment of young people with tertiary education, especially of those with social sciences or humanities degrees.

Young people, aware of such labour market trends and of numerous student job possibilities, often prolong their studies in order to keep their student job as long as they can, especially in their final years of studies. This can lead either to non-graduation or to later degree employment on the same position of term-time employment, i.e. position not requiring higher education and not related at all to student's professional or academic degree. Apart from that, some of the students attend college only for the possibility to work on student contracts in the first place, a problem recognized by the Ministry of Science and Education itself [21] and the one hardly solvable by the proposed changes of the new student employment regulation mechanism. Introducing the minimum wage of student work and providing the possibility of that kind of work for all students could potentially lead to its greater misuse, in the ways described both in this and in the earlier chapter.

A more suitable solution for all the discussed student employment irregularities would be a better and more widespread use of student practice. Although some students do have to complete an internship during their formal education, they usually don't get the opportunity to improve their knowledge and professional skills or to prove themselves, since their employers often give them mundane and low priority tasks [33; p.448]. Employers do so because students are not always available and cannot be employed full time, but also because interns are not required to stay with the employer upon the completion of internship [33; p.448]. That way employers could invest time, money and other resources into the professional training of a student who will after the graduation use is elsewhere. Given reasons are yet another incentive for the student employment use, especially that of senior students who are available for higher intensity employment and who already have some usable knowledge and skills so employer don't have to invest much in their training.

A simple imposition of the student practice use isn't the answer to student term-time employment misuse. Neither is the simple broadening or restricting the possibilities of such employment. The first step to the improvement of students' position on the labour market is to appropriately follow and analyse the patterns of their term-time and graduate employment, their motivations and academic and professional pathways. Currently there is a serious lack of the relevant student population data suitable for that kind of analysis.

## REMARKS

<sup>1</sup>Contract for work, defined by the Civil obligations act [34], as opposed to the standard employment contract, does not imply permanent and continuous execution of certain work, but execution or making of a certain work product [31; p.41]. Working on this kind of contract, as on the student contract for work, is taxed as a second income, meaning it is tax free to a certain extent.

<sup>2</sup>Apsolvent is a student who attended all of his mandatory courses but hasn't yet graduated.

<sup>3</sup>Students with higher education background have parents of which at least one has attained a higher education degree (EUROSTUDENT, 2015).

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# THE NEXUS OF ETHICAL LEADERSHIP, JOB PERFORMANCE, AND TURNOVER INTENTION: THE MEDIATING ROLE OF JOB SATISFACTION

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## ABSTRACT

This study aims to examine the impact of ethical leadership on employees' job satisfaction, job performance, and turnover intention. A conceptual framework is developed which integrates job satisfaction as a mediating mechanism in explaining the nexus among ethical leadership, employee job performance, and turnover intention. The proposed model is tested by using the data collected from a sample ( $n = 196$ ) of tourist companies in Pakistan. The results reveal that ethical leadership has a positive effect on employees' job satisfaction, job performance and negative effect on employees' turnover intentions. Further, job satisfaction mediates the effect of ethical leadership on employees' job performance and turnover intentions. The findings recommend that the demonstration of ethical leadership behaviours by managers at the workplace increases the likelihood of employees' job satisfaction and performance, while reducing their intention to leave the job. This study elucidates that, in Pakistani tourism sector, ethical leadership plays a key role in achieving performance goals. Future research could analyse the said nexus in different sectors and across different cultures while considering other measures of individual performance. The originality of this study is theorizing as well as empirically testing the intervening mechanism of job satisfaction in probing the linkages among ethical leadership, job performance, and turnover intention in Pakistani workplace context.

## KEYWORDS

ethical leadership, job performance, turnover intention, job satisfaction

## CLASSIFICATION

JEL: D19, D23, J28, M10

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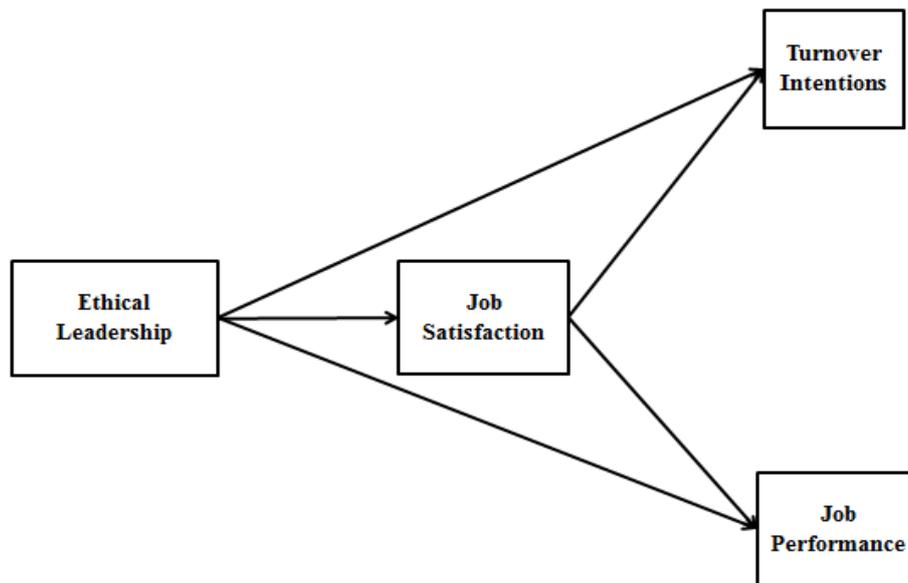
## INTRODUCTION

Ethical leadership is an imperative element for organizations because it helps organizations to decrease business expenditures through fair and moral treatment of its employees as well as other resources [1]. Ample research has investigated the positive role of ethical leadership in lessening the destructive behaviours of employees and to discourage immoral workplace practices [2, 3]. However, relatively less attention has been paid to probe the nexus of ethical leadership, employees' job performance [4-6] and their intention to leave the organization [7]. There are only few studies that considered social learning context of Brown, Treviño, and Harrison [8] as an influential model to explain how and why ethical leadership links and affects employee job performance [9]. The primary assumption of this model suggests that ethical leader affect employees' behaviours through role modelling. By practicing ethical management, e.g. advocating the ethics and compensating employees on the basis of ethical agreements, ethical leader as a role model can inspire employees not to indulge in such behaviours which can harm their job performance [4, 8].

Besides little attention of scholars on the association of ethical leadership, employees' job performance, and their turnover intention, studies focusing on mediating mechanisms – by which 'ethical leadership-performance' nexus is elucidated – are yet very hard to find [4-6]. A limited amount of literature explicates the mechanisms through which ethical leadership is linked with employees' job performance [10] and turnover intention [11]. Therefore, the dearth of literature on 'ethical leader employee' nexus seems to highlight the need for further investigation into the mechanisms through which ethical leadership puts a positive influence on employees' job performance and turnover intention. Since prior research has mostly emphasized the trust as a gauge to analyse the worth of the aforementioned nexus [10], this research, on the other hand, suggests that aligning the objectives between leaders and employees may serve as a significant mechanism to explain how ethical leadership is linked with employee job performance and turnover intention. In particular, following Brown et al. [8] social learning context, it is supposed that ethical leaders impart similar values and objectives among their employees [12]. Consequently, that increases the chances of employees to adopt and exhibit such behaviours which contribute to the accomplishment of these objectives [5].

Past studies connected the motivational effects of ethical leadership with motivational tendency, which is essential for a high quality and meaningful linkages between leaders and employees, and its intervening effect on the employee job performance [8, 13] and turnover intention. To study aforementioned nexus, it is still necessary to pay adequate attention to include pleasure factor which exists at the individual level. Consistent with that conception, employee job satisfaction is proposed as a pleasure factor which may be of considerable worth in further exploration of 'ethical leadership-job performance', and 'ethical leadership-turnover intention' linkages. Job satisfaction is a positive behaviour which appears as a response of an employee towards his/her job [14, 15]. Besides affecting employees' job performance, job satisfaction may also act as an intervening variable between effective leadership styles and employees' behavioural outcomes [11]. Drawing upon this argument and considering Brown's social learning context of ethical leadership, it is supposed that ethical leaders' positive communication, and open and clear dissemination of information regarding unethical behaviour provides employees an example of a suitable attitude to elucidate what would be effective at job. This precision and explicitness in expectations elevate employees' positive attitude toward job and job satisfaction as well [8]. Thus, it is imperative to investigate the association between ethical leadership, employees' job performance, and turnover intention by adding employees' job satisfaction theoretically as an intervening variable.

This study recognizes and analyses the role of a pleasure factor i.e. employees' job satisfaction, as an important mechanism by which ethical leadership may have a positive effect on employees' job performance and turnover intention. By incorporating the employees' job satisfaction, previous calls are addressed to find the mechanisms which assist us to develop an understanding of how ethical leadership influences employees' job performance [16] and turnover intention [7]. This study employed the theories of social learning and ethical leadership to address the previously discussed issues. Through these theories, this study develops the framework which is depicted in Figure 1.



**Figure 1.** Conceptual framework.

## LITERATURE AND HYPOTHESES DEVELOPMENT

### ETHICAL LEADERSHIP AND JOB SATISFACTION

According to Treviño, Brown, and Hartman [17], an ethical leader is one who is open to novel ideas, trustworthy, honest, and strictly follows moral principles. Resick, Hanges, Dickson, and Mitchelson [18] stated the following characteristics of an ethical leader: a) being moral and having ethical character; b) considers society and people; c) motivates and empowers the employees, and d) manages ethical accountabilities. Similarly, O'Connell and Bligh [19] refer to nine attributes of ethical leadership which are: 1) ethical leader has ethical sight; 2) involves in ethical decision-making; 3) gives priority to long-term decision-making; 4) treats the employees fairly; 5) is role model of ethical behaviour; 6) communicates importance of ethics to the employees; 7) understands himself and those he/she works with; 8) arranges trainings for employees to teach behaving ethically, and 9) holds others accountable for their ethical actions. According to Auer Antoncic and Antoncic [20] job satisfaction is the degree of liking or disliking the job by employees. Thus, job satisfaction or dissatisfaction is a response that an employee shows after being appraised about his/hertask against set standards.

Brown et al. [8] advocated that ethical leadership is strongly associated with employees' job satisfaction. They further accentuated that employees exhibit greater job satisfaction to an ethical leader who "disciplines wrong-doers, treats their followers fairly and considerately, and exhibits ethical leadership style" [8]. An ethical leader is fair, sincere, open, and honest, fosters job satisfaction of his/her subordinates, and elevates their affective organizational

commitment i.e. subordinates feel proud for being part of that organization and care for better future of the organization [16]. Consequently, employees want to payback with a positive attitude which affects followers' satisfaction positively [22, 23]. Ethical leaders are always fair in decision-making process related with employees, such as job designing, job evaluation, and promotions, thus building trust among employees [12] and leading them towards pleasant feelings of job i.e. job satisfaction [22, 24]. Kim and Brymer [25] empirically found that ethical leadership positively influences the followers' job satisfaction. Thus, we hypothesize:

H1: *Ethical leadership has positive nexus with job satisfaction.*

## **ETHICAL LEADERSHIP AND JOB PERFORMANCE**

Job performance is referred to 'how well employees do their job-related tasks' [26]. Ample of previous research has shown the connection between ethical leadership and employees' outcomes including employees' deviant behaviours, citizenship behaviours, and ethical cognition and conduct [4, 13]. Ethical leaders consider themselves as trustworthy role models and important source of knowledge through their "normatively appropriate" behaviour [8; p.120] and open communication of moral values [27]. This helps to establish a mutual understanding of acceptable behaviours among employees, to enhance their learning, and to imitate the behaviours of leaders, which in turn fosters their work-related performance [4]. Social learning theory provides an inclusive model to elucidate how ethical managers impact the employees' job performance [28]. This theory suggests that ethical leaders use their influence on employees' behaviour, primarily using role modelling [29]. Thus, role modelling offers to employees the basis for learning those behaviours which are essential to exhibit well on job [27]. Ethical leaders are smart and genuine role models capturing the attention of their employees and affect them successfully by assisting to get their potential at work [28]. Putting together, it is emphasised that ethical leaders positively affect employees' job performance using reward and punishment, and guide employees in a right way to perform the job [12]. Ethical leaders also emphasise on two-way communication with employees, therefore, employees feel more responsible and invest extra efforts to perform their job well [30]. Employees feel that their leaders have the best interest and care for them. In return, employees work harder and try to payback with their improved performance [31]. Therefore, it is postulated that:

H2: *Ethical Leadership has positive influence on employees' job performance.*

## **ETHICAL LEADERSHIP AND EMPLOYEES' TURNOVER INTENTION**

Employees' turnover intention refers to the membership termination intention of a person from an organization where he/she is getting a financial return. There can be several reasons of employee turnover, ranging from external antecedents (e.g., employment opportunities), to organizational antecedents (e.g., leadership style and workplace environment), to personal antecedents (e.g., dissatisfaction from the job) [32].

Researchers have been studying the effects of ethical leadership on organizational and employees' behavioural outcomes. In this context, few tried to empirically analyse the effect of ethical leadership on employees' turnover intention. Brown et al. [8] argued that leadership style in any organization should be influential. This implies that managers' ethical style of leadership should influence employees' job response [33]. Ethical leadership is important for organizational operations [2], because in high power-distance firms, ethical leaders are more likely to develop emotional ties with employees [34], consequently, reinforcing the positive effects on employees' job response [33]. Therefore, when employees experience ethical treatment from their managers, they feel sense of security, support [35], fair treatment [36], and also feel that their primary requirements are fulfilled [37]. Furthermore, employees may

establish psychological agreements which may strengthen the shared commitment obtained by managers and employees to work for joint well-being [38]. As managers demonstrate the ethical style of leadership, employees exhibit useful positive attitudes and behaviours regarding job, thereby minimizing the likelihood of quitting the job and/or moving to some other organization. Existing literature also recommends this nexus, see e.g. [39-42]. Thus, we hypothesize that:

H3: *Ethical Leadership has a negative relationship with employees' turnover intentions.*

## **JOB SATISFACTION AND JOB PERFORMANCE**

Ethical leaders allow employees to participate in decision making using two-way communication. As a result, employees feel that they are an important part of the organization, thereby demonstrate satisfaction from the job and put extra efforts which improve their job performance [4]. Likewise, authors in [43] revealed a positive association between job satisfaction and job performance. Managers can foster employees' job performance using managerial strategies to augment job satisfaction [44]. A highly satisfied worker is thought to put extra efforts to perform work more effectively and efficiently, which in turn increases the overall work productivity. Chen, Zhao, Liu, and Dash Wu [45] found out that job satisfaction positively influences job performance. Therefore, following hypothesis is suggested:

H4: *Job satisfaction has positive nexus with job performance of employees.*

## **JOB SATISFACTION AND EMPLOYEES' TURNOVER INTENTIONS**

Job satisfaction has been long identified as a valuable factor to explain turnover intention [46, 47]. Employees with a greater level of job satisfaction are more expected to associate with their organizations. However, dissatisfied employees show a behavioural intention to leave their jobs and try to find a substitute. The nexus between job satisfaction and turnover intention has been studied widely in organizational research, and findings by and large depict that job satisfaction decreases turnover intention [48]. Muchinsky and Tuttle [49] analysed 39 studies in a meta-analysis and found that job satisfaction negatively affects the employees' turnover intention. Likewise, Tett and Meyer [50] using meta-analysis found that job satisfaction is negatively linked to turnover intention. Thus, following hypothesis is proposed:

H5: *job satisfaction has negative nexus with employee's turnover intentions.*

## **MEDIATION OF JOB SATISFACTION**

Job satisfaction refers to the positive and pleasurable emotional condition independently to employees' experiences at the workplace. Despite the personal attributes and job design, supervision is crucial to determine employees' performance and perception about the organization [51, 52]. The relationship among leadership, job satisfaction, job performance, and turnover intention is well established in literature [27, 46]. However, these connections were analysed separately and ignored a pleasure factor (i.e., job satisfaction) as a potential mediating mechanism to check the effects of ethical leadership on employees' job satisfaction, job performance, and turnover intentions.

Moreover, it is argued that employees who are satisfied with their jobs perform better and prefer to stay associated with the organization [53]. A satisfied employee puts his/her energy to enhance work-related performances. Given that employee job satisfaction is closely linked with supervisor's/leaders' behaviour, ethical leaders – through demonstrating their open, fair, and ethical behaviour – enhance employees' job satisfaction which in turn increases employee job performance and elevates employees' identity and commitment towards organization i.e. they feel proud of being part of that organization and want to stay in the

organization [16]. Therefore, ethical leadership is expected to improve employee job performance and reduce turnover intention through increasing employee job satisfaction. By keeping this view in mind, following hypotheses are proposed:

H6a: *Job satisfaction mediates the effect of ethical leadership onto employees' job performance.*

H6b: *Job satisfaction mediates the effect of ethical leadership onto employees' turnover intention.*

## **METHODOLOGY**

### **RESEARCH BACKGROUND AND AREA OF SAMPLING**

The purpose of this study is to examine the effect of ethical leadership onto employees' job performance, and their intentions to leave the organisation directly as well as via job satisfaction. The study is carried out in tourism industry where the data were collected from both public and private tourism companies of Pakistan. The tourism industry provides its services to the customers who want to visit and tour Pakistan-wide different places. Their services include transportation, residence, food and/or photography. Respondents of the study consisted of employees working in tourism industry. We asked employees about the ethical behaviour of their leaders, their satisfaction from work, intentions regarding leaving their current company, and their feeling about their performance on the job.

### **SAMPLE AND PROCEDURE**

Tourism firms are selected from three cities (Lahore, Faisalabad, and Multan) of Punjab province, Pakistan. These three cities have the most prosperous tourism industry. This industry is selected because of its significant influence on economy, culture, environment, and society [54, 55]. In the recent years, Pakistani tourism industry has regained the momentum after a decade of socio-political decline in the territory. Therefore, this industry emphasises the awareness of and exercising the ethical practices. The demonstration of ethical practices by the managers of Pakistani tourism firms is the need of time, thus they initiate incorporating the ethical style of leadership in their strategic plans to enhance employees' level of job satisfaction and behavioural outcomes. Demonstration of ethical leadership is also important for long-term sustainability. Consequently, the scholars put more efforts into studying the effects of ethical leadership in this sector from different perspectives.

Data were collected from two main sectors: travel agencies and hotels. English serves as the formal language of tourism firms which participated in this research. White-collar employees, were approached for data collection. Questionnaires were distributed only to those having their bachelor or master degrees in English as a medium of instruction. Therefore, the questionnaire was administered in the English language which is in line with the method followed by earlier researchers in Pakistan [56, 57]. Participating firms were approached in these cities using a blend of self-contacts. This is a useful and effective method in Pakistan; a collectivistic society [27]. Out of 250 questionnaires delivered to the companies (one questionnaire for one firm), 198 were received-back with a response rate of 79,2 %. Two questionnaires were removed from the final sample due to incomplete response. Finally, data of 196 firms were used for further analysis. Of these 196 firms, 48,6 firms established for more than ten years and 62,5 firms had lesser than 150 employees.

### **MEASURES**

A 10-item scale, adapted from Brown et al. [8], was used to measure ethical leadership on 5-point Likert scale ranging from 1 – Strongly Disagree to 5 – Strongly Agree. Items were based on employees' experience as what they feel about their leaders and up to what extent their leaders care and involve them in the decision-making process. The value of Cronbach's

Alpha reports high internal consistency of the scale ( $\alpha = 0,901$ ). Job satisfaction scale was adapted from Yang and Islam [58] and was measured using a 5-point Likert scale from 1 – Very unsatisfied to 5 – Very satisfied. The value of Cronbach's Alpha reports good internal consistency of the scale ( $\alpha = 0,894$ ). Employee turnover intention was measured using 5-point Likert scale ranging from 1 – Strongly Disagree to 5 – Strongly Agree [59-61]. The value of Cronbach's Alpha reports high internal consistency of the scale ( $\alpha = 0,844$ ). A 14-item scale was adapted from Lynch, Eisenberger, and Armeli [62] to measure job performance using a 5-point Likert scale ranging from 1 – Strongly Disagree to 5 – Strongly Agree. The value of Cronbach's Alpha reports high internal consistency of the scale ( $\alpha = 0,925$ ).

## **DATA ANALYSIS**

Structural equation modelling (SEM) was used to analyse the hypothesized relationships as it provides some benefits over conventional multivariate analytical methods [63]. Particularly, partial least square (PLS), a strong analytical technique was employed [64], which establishes a soft modelling via robust and stringent statistical methods [65]. PLS is an appropriate analytical method for this research because it is a statistical technique mostly expected for causal-predictive investigation which has validated valuable states of great complexity but less hypothetical knowledge [66]. Therefore, PLS is sufficient to establish and develop the theory [65] or to check the theory which is in its initial phase [67], hence very suitable in this research. In addition, SEM is especially suggested to analyse the mediation [68], and ample of research work employed this statistical approach in estimating such relationship using PLS [69-71]. Likewise, the PLS through WarpPLS 5.0 was employed to test the hypotheses and goodness of the model fit. SPSS 22.0 was also used to get socio-demographical descriptive correlational data exploration.

Since this study employed the Baron and Kenny [72] technique to test the mediation, PLS-SEM is suitable for the analysis. According to their technique, three conditions are essential to develop mediation. First, the independent variable (ethical leadership) should be significantly associated with dependent variables (job performance and turnover intention). Second, the independent variable should be significantly connected to the mediator (job satisfaction). Last, on the regression of dependent variable, the mediating variable(s) should be significantly associated with the dependent variable. Furthermore, full mediation exists is the independent variable exhibits zero or insignificant effect on the dependent variable after introduction of the mediating variable.

## **RESULTS**

First, confirmatory factor analysis (CFA) was employed to check the factor loadings, validity (discriminant and convergent), and reliability as shown in Table 1. Factor loadings of all indicators are larger or equal to 0,50 [73], and are significant at least at the level of 0,05 [74, 75]. The findings suggest that the instrument of this study has successfully crossed the threshold of the criteria for convergent validity [76]. Discriminant validity is checked by comparing the square roots of average variances extracted (AVEs) with corresponding inter-construct correlation. The square roots of AVEs for the latent constructs are given on diagonal within parentheses in Table 2. It is observed that the values of square roots of AVEs for every latent construct are higher than that of any correlation of the respective latent construct. Therefore, it is inferred that the measurement model has satisfactory discriminant validity [75]. The reliability of measurement models is evaluated through Cronbach's alpha (CA) and construct reliability (CR). The acceptance level of CA and CR is larger than 0,70. The values of CR and CA also confirm that the constructs' reliability.

**Table 1.** Factor Loadings, Validity, and Reliability.

Items	EL	TI	JS	JP
EL1	0,704			
EL2	0,742			
EL3	0,901			
EL4	0,878			
EL5	0,815			
EL6	0,887			
EL7	0,844			
EL8	0,999			
EL9	0,769			
EL10	0,824			
TI1		0,964		
TI3		0,952		
TI4		0,951		
TI5		0,958		
TI6		0,961		
TI7		0,952		
EJS1			0,689	
EJS2			0,758	
EJS3			0,698	
EJS4			0,727	
EJS5			0,724	
EJS6			0,764	
EJS7			0,769	
EEJS2			0,784	
EEJS3			0,786	
EEJS4			0,756	
JP1				0,771
JP2				0,798
JP4				0,787
JP5				0,726
JP6				0,825
JP7				0,728
JP8				0,710
JP9				0,683
JP10				0,762
JP11				0,758
JP12				0,775
JP13				0,781
JP14				0,717
JP15				0,797
JP16				0,709
CR	0,919	0,887	0,913	0,935
CA	0,901	0,844	0,894	0,925
AVE	0,535	0,574	0,515	0,500
Skewness	-0,750	0,284	-1,214	-1,258
Kurtosis	0,027	-0,752	2,113	2,331

In a nutshell, measurement model goes through successfully the number of stringent analyses of convergent validity, discriminant validity, reliability, and multicollinearity. The findings reveal that model fulfils the broadly accepted data validation criteria and recommend that findings of SEM-PLS can be trusted and do not have data measurement issues [76].

Table 2 shows the means, standard deviations, and correlations of the variables. The low and medium level correlations confirm the absence of collinearity among the indicators.

**Table 2.** Descriptive Statistics.

Variable	Mean	SD	1	2	3	4
1. Ethical leadership	3,7330	0,85989	(0,732)			
2. Job satisfaction	3,9053	0,76005	0,448***	(0,758)		
3. Job performance	4,0211	0,71005	0,410***	0,752***	(0,718)	
4. Turnover intention	2,6769	1,0265	0,280**	0,880***	-0,074**	(0,703)

\*\*statistically significant at 10 %

\*\*\*statistically significant at 1%

SEM-PLS was performed using WarpPLS 5.0 to test the proposed hypotheses. The goodness of the model fit is ensured through average path coefficient (APC), average  $R^2$  (ARS), and average variance inflation factor (AVIF). Values of the APC (0,25,  $p < 0,001$ ) and ARS (0,242,  $p < 0,001$ ) are significant as well as AVIF (1,327) is less than 5. It is recommended that the model be a good fit of the data since relying on results is better than guessing the relationships [76, 78]. Table 3 presents main results related to hypotheses testing. Results show that ethical leadership has a positive relationship with employees' job satisfaction ( $\beta = 0,48$ ,  $p < 0,001$ ) and job performance ( $\beta = 0,113$ ,  $p < 0,001$ ), thus supporting the first two hypotheses. Furthermore, ethical leadership negatively influences the employees' turnover intention ( $\beta = 0,273$ ,  $p < 0,01$ ), which confirms hypothesis 3. Job satisfaction positively affects employees' job performance ( $\beta = 0,712$ ,  $p < 0,001$ ), thereby, hypothesis 4 is also accepted. Job satisfaction has an insignificant connection with turnover intention ( $\beta = 0,142$ ,  $p < 0,11$ ).

**Table 3.** Hypotheses testing.

Path	Direct	Indirect	Total
EL → JS	0,483***		0,483***
EL → JP	0,113***	0,344***	0,457***
EL → TI	-0,273**	0,069**	-0,204**
JS → JP	0,712***		0,712***
JS → TI	0,142		0,142

\*\*statistically significant at 10 %

\*\*\*statistically significant at 1%

Hypotheses 6a and 6b propose that the employee job satisfaction serves as an intervening mechanism through which ethical leadership indirectly optimise the employee job performance and minimises the likelihood of employee turnover. The mediation analysis for ethical leadership-job performance nexus fulfils the assumptions and supports presence of partial mediation such that indirect effect of ethical leadership on employee job performance through job satisfaction is which supports hypothesis 6a. However, for ethical leadership-turnover intention linkage the mediational model does not fulfil the third condition which states that intervening variable (job satisfaction) must be significantly linked with dependent variable (i.e. turnover intention). Hence, the data does not support our hypothesis 6b which states that job satisfaction mediates the effect of ethical leadership on employee turnover intentions.

## DISCUSSION

Previous studies have highlighted the significance of leadership regarding employees' job performance and turnover intention. Nevertheless, relatively limited attention has been paid to understand the underlying mechanisms through which ethical leaders affect employees attaining required and/or desired results [79]. This study responds to the calls that ask for investigation of ethical leadership and employee job outcomes nexus through a mechanism as it considers employee job satisfaction as a mediating mechanism to study the aforementioned linkages. Given that employees' job satisfaction is imperative to comprehend the effect of ethical leadership on the behavioural consequences, therefore, it is worthy of investigating the association between leadership styles and employee behaviours. This study is significantly different from other researches which just focused on the nexus of leaders and employees as a major mechanism in elucidating the influential role of ethical leadership to shape employees job performance and intention to leave the organizations. In sum, the results of this study propagate that ethical leadership can foster employees' job performance and decrease their turnover intention through enhancing their job satisfaction.

The results suggesting that employees' perception of ethical leadership is positively associated with their satisfaction are novel and theoretically captivating because of its incorporation of the ethical style of leadership with the inspirational tendency of job satisfaction. These results are encouraging, of particular, when pondering that researchers suggested examining the methods through which employees' job satisfaction can serve as a means to employee outcomes. As per practical viewpoint, these results show the importance of ethical leadership to augment employees' job satisfaction. This study contributes by supporting the academic theoretical contention that job satisfaction is linked with job performance.

In addition, this study has not just recognised job satisfaction as a mechanism by which ethical leadership is connected with employees' job performance and turnover intention but also presented social learning theory [28] as a descriptive model to explain when and how ethical leadership affects employees' job-related behaviours and outcomes. In line with the conceptualization of Brown et al. [8], it is advocated that job satisfaction is a significant mediating mechanism in the relationship of ethical leadership and employees' job performance. By applying the SEM-PLS, this research denotes a significant effort to link job satisfaction in association between leaders and employees to elucidate the connections among ethical leadership, employees' job performance, and their turnover intention.

Although this research does not analyse whether ethical leadership differs in general because the data were gathered from Pakistan; which varies considerably from a number of western developed economies. As a collectivist society with powerful religious effect on almost all the perspectives of life [80], studying ethical leadership concept and westernized social learning theory on data gathered from Pakistan seems to be very vigorous. The findings have proved that majority of the hypotheses is accepted, thus, this study contributes to the cross-cultural validity of the ethical leadership, employees' job satisfaction, performance and turnover intention research.

## MANAGERIAL IMPLICATIONS

Despite the several conceptual implications, the results of this study also have considerable practical implications. The managers of the organizations should worth ethics and consider it as a major rock on which basis the culture of their organizations is constructed. For instance, leaders' honour, credibility, and faith are expected to develop a culture where employees' job satisfaction becomes the custom. Particularly, the results recommend that ethical leadership has a normative character by inspiring ethical attitudes among the employees [8, 16] as well

as positive influence on employees' job performance by fostering their job satisfaction and arranging the objectives between leader and employee. The argument that ethical leadership influences employees' job performance, establishes the scenario that managers should emphasize ethics as a compulsory part of their managers' training and development programs. From a strategic perspective, the results further suggest that organizations should employ ethics as a significant measure in the recruitment and promotional plans of the employees. This perspective is likely to get support from the positive outcomes of ethical leadership on employees' job satisfaction, performance and turnover intention.

## **LIMITATIONS AND FUTURE DIRECTIONS**

This study also has few limitations, especially related to research design. This is cross-sectional study by design, no conclusion regarding causality can be induced. Likewise, it could be possible that job satisfaction develops employees' views of ethical leadership (i.e. rather ethical leadership fostering job satisfaction) alongside the causal relationship we proposed. So, future guidelines of this study should be longitudinal to solve the causality problems. Additionally, using the longitudinal method to this study stream would permit apprehending more data points provided during the period of time and would assist elucidate how employees' job satisfaction may affect employees' job performance and their intention to leave the organization. Next, although the sample of this study was enough to notice important results in the mediation analysis, the future study needs to use large sample size which permits to analyse this model with a more robust analytical way like multilevel SEM [81].

Finally, this research shows the relationship of employees' job satisfaction, performance, and turnover intention with only one style of leadership i.e. ethical leadership. Many of characteristics of another type of leadership can also overlap e.g. transformational leadership. From an academic point of view, the relationship of these variables can also be explained by other styles of leadership which was not tested in this study.

## **CONCLUSION**

The major purpose of this study was to excavate our comprehension regarding the nexus of ethical leadership, employees' job satisfaction, performance, and turnover intentions in the tourism sector of Pakistan. The context of social learning theory was employed to establish further understanding of the relationship between ethical leadership and employees' behavioural outcomes. The data were gathered from Pakistan, which is performing progressively vital role in the world economy in general and in South Asia in specific. If Western theories are analysed in non-Western contexts, scholars and experts would have firm assurance regarding the wide applicability of these theories to other parts of the world [82]. This research gives better understanding regarding the applicability of notions of ethical leadership, job satisfaction, job performance, and turnover intention in Pakistan. Yet this research is just a bubble in the sea, we expect that it will motivate other researchers to endure to spread the insights of these conceptions in other countries.

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# CITIZEN DATA SCIENCE FOR SOCIAL GOOD IN COMPLEX SYSTEMS

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## ABSTRACT

The confluence of massive amounts of openly available data, sophisticated machine learning algorithms and an enlightened citizenry willing to engage in data science presents novel opportunities for crowd sourced data science for social good. In this submission, I present vignettes of data science projects that I have been involved in and which have impact in various spheres of life and on social good. Complex systems are all around us: from social networks to transportation systems, cities, economies and financial markets. Understanding these complex systems may lead to solutions for problems ranging from famines, global crises, poverty, climate change and sustainable living despite over-population. Big data and citizen data science allows unprecedented computational power and collective intelligence to be brought to bear on fundamental challenges facing humanity like poverty, diseases, famines and developmental challenges.

## KEYWORDS

citizen data, Zenodo, complex systems

## CLASSIFICATION

JEL: C51, C88

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## **INTRODUCTION**

The confluence of massive amounts of openly available data, sophisticated machine learning algorithms and an enlightened citizenry willing to engage in data science presents novel opportunities for crowd sourced data science for social good. In this submission, I present vignettes of data science projects that I have been involved in and which have impact in various spheres of life and on social good.

Complex systems are all around us: from social networks to transportation systems, cities, economies and financial markets. Understanding these complex systems may lead to solutions for problems ranging from famines, global crises, poverty, climate change and sustainable living despite over-population. Big data and citizen data science allows unprecedented computational power and collective intelligence to be brought to bear on fundamental challenges facing humanity like poverty, diseases, famines and developmental challenges.

## **CRIME IN SOCIETIES**

Using openly available data from the US Census and FBI combined with machine learning techniques, we uncover novel patterns of crime in US cities [1, 2]. Our results have implications for public policy especially the number of police that should be allocated in larger cities and budget for law enforcement.

We look at freely available data about violence and assault on women in US college campuses. Using machine learning techniques we uncover trends and patterns that highlight the need for protection of women and greater transparency in how universities handle cases of assault [3]. We have also built and freely shared tools that allow people to interact with the code and data [4]. These tools have the dual purpose of achieving crowdsourced citizen data science as well as outreach and engagement, thereby spreading awareness of relevant social issues.

## **PUBLIC HEALTH AND EMERGING DISEASES**

Global pandemics are on the rise. Novel disease like Zika and Ebola virus jump from species to species and ultimately affect humans. Using data from the Center for Disease Control (for West Nile virus) coupled with advanced machine learning techniques, we predict species that may likely be infected in the next pandemic [5]. We also predict infectivity of viruses from very sparse experimental data [3]. These kinds of techniques can help rapidly predict the potential of emerging viruses to spread, especially when we have very little experimental data about them.

In rare cases, the immune system can attack the cells of the host organism causing autoimmune diseases. We implemented a computational framework that combines bioinformatics and network analysis with an emerging targets platform [4]. The computational framework can be used to find drug targets for autoimmune diseases. It can also be used to find existing drugs that can be repurposed to treat autoimmune diseases based on networks of interactions or similarities between different diseases. Our computational framework uses open data on drug targets to find novel therapeutics for autoimmune diseases and potentially even other dysfunctions.

The code and associated material is available online [6]. An open source framework enables anyone with a computer and an internet connection to start searching for drug targets. Such kinds of frameworks can enable citizen scientists to contribute to drug science.

## **SOCIETY AND DEVELOPING NATIONS**

Scientific collaboration networks are an important component of scientific output and contribute significantly to expanding our knowledge and to the economy and gross domestic product of nations. We examined data from the Mendeley scientific collaboration network. We analyzed this data using a combination of machine learning techniques and dynamical models [7]. We highlight inequalities in global networks of scientific collaboration. This has implications for how developing nations invest in science and are able to make economic progress. Our model and analysis gives insights and guidelines into how scientific development of developing countries can be guided. This is intimately related to fostering economic development of impoverished nations and creating a richer and more prosperous society.

## **CITIZEN DATA SCIENCE FOR COMPLEX SYSTEMS**

Complex systems are all around us: from social networks to transportation systems, cities, economies and financial markets. Understanding these complex systems may lead to solutions for problems ranging from famines, global crises, poverty, climate change and sustainable living despite over-population. Understanding complex systems and solving real world problems will need building multi-scale computational models that integrate understanding from multiple levels of aggregation. Such computational models will have to be 1) scalable, 2) need to make inferences from huge amounts of data (big data) and 3) practitioners will have to talk with different stakeholders to understand problems and communicate solutions to them. Computational models that scale will be critical in understanding complex systems: disease models, socio-economic systems, biological systems.

Decentralized non-institutional collaborative networks like the Ronin Institute will enable greater citizen involvement and democratize science [8]. Decentralized collaboration networks can accelerate scientific discovery [9]. Such initiatives have the potential to engage new scientists in solving the problems of humanity despite the funding problems in science [10].

All the accompanied code and analysis are available online [11]. We hope this will allow any citizen scientist to engage in model building and hypothesis testing.

We need citizen scientists enabled with open data and freely available computational techniques to engage with humanity's pressing problems. Big data and citizen data science allows unprecedented computational power and collective intelligence to be brought to bear on fundamental challenges facing humanity like poverty, diseases, famines and developmental challenges.

## **ACKNOWLEDGEMENTS**

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# THE 'CRISIS OF NOOSPHERE' AS A LIMITING FACTOR TO ACHIEVE THE POINT OF TECHNOLOGICAL SINGULARITY

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## ABSTRACT

One of the most significant developments in the history of human being is the invention of a way of keeping records of human knowledge, thoughts and ideas. In 1926, the work of several thinkers such as Edouard Le Roy, Vladimir Vernadsky and Teilhard de Chardin led to the concept of noosphere, the idea that human cognition and knowledge transforms the biosphere into something like a thinking layer of the planet. At present, it is commonly accepted by some thinkers that the Internet is the medium that will give life to noosphere. According to Vinge and Kurzweil's technological singularity hypothesis, noosphere would in a future be the natural environment in which a 'human-machine superintelligence' would emerge to reach the point of technological singularity. In this article we show by means of numerical models that it is impossible for our civilization to reach the point of technological singularity in a near future. We propose that this point could be reached only if Internet data centers were based on "computer machines" that are more effective in terms of hardware and power consumption than the current ones. Finally, we speculate about 'Nooscomputers' or N-computers, as hypothetical machines oriented not only to the management of information, but also knowledge, and much more efficient in terms of electricity consumption than current computers. Possibly a civilization based on N-computers would allow us to successfully reach the point of technological singularity.

## KEYWORDS

noosphere, technological singularity, omega point, energy consumption, Malthusian growth model, S-curve, N-computer

## CLASSIFICATION

JEL: O10, Q55

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## INTRODUCTION

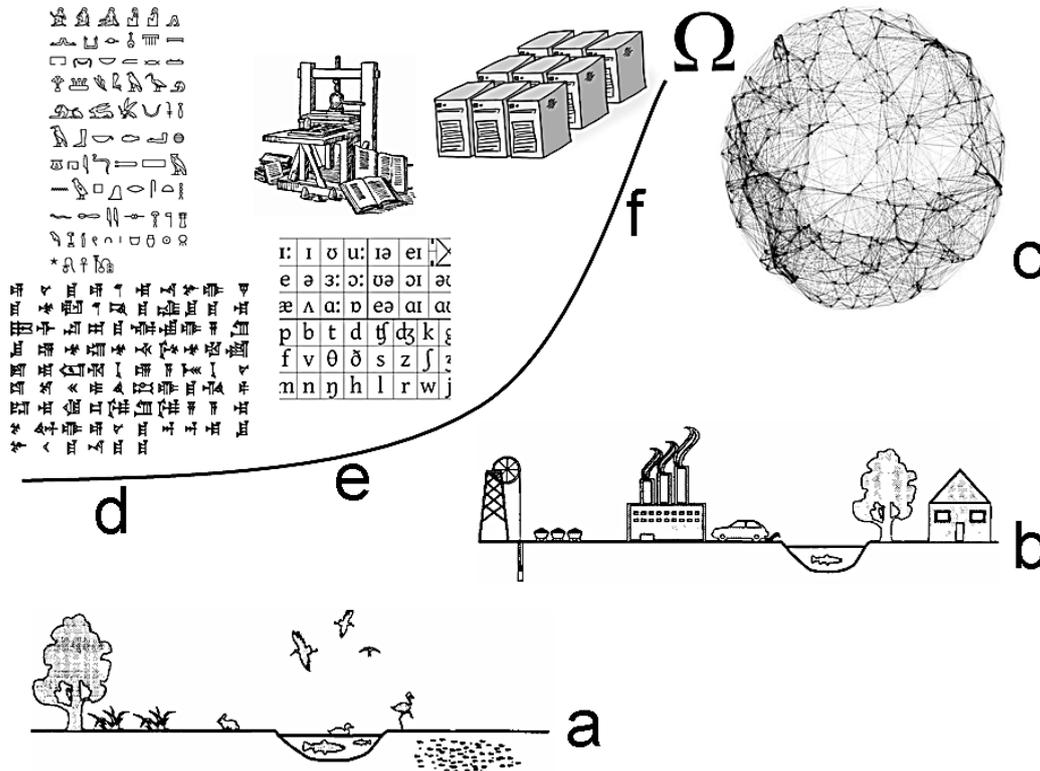
One of the most significant developments in the history of human being is the invention of a way of keeping records of human knowledge, thoughts and ideas. The storage of knowledge is a sign of civilization, which has its origins in ancient visual languages e.g. in the cuneiform scripts and hieroglyphs until the achievement of phonetic languages with the invention of Gutenberg press. In 1926, the work of several thinkers such as Edouard Le Roy, Vladimir Vernadsky and Teilhard de Chardin [1] led to the concept of noosphere, thus the idea that human cognition and knowledge transforms the biosphere coming to be something like the planet's thinking layer. At present, is commonly accepted by some thinkers that the Internet is the medium that brings life to noosphere. Hereinafter, this essay will assume that the words Internet and noosphere refer to the same concept, analogy which will be justified later.

In 2005 Ray Kurzweil [2] published the book *The Singularity Is Near: When Humans Transcend Biology* predicting an exponential increase of computers and also an exponential progress in different disciplines such as genetics, nanotechnology, robotics and artificial intelligence. The exponential evolution of these technologies is termed as Kurzweil's 'Law of Accelerating Returns', leading this rapid development of human beings to a situation that is known as 'technological singularity'. According to Vinge [3] and Kurzweil's technological singularity hypothesis, noosphere would be in the future the natural environment in which human-machine superintelligence will emerge after to reach the point of technological singularity.

According to James Lovelock's Gaia hypothesis (Fig. 1) the living and non-living parts of the planet form a self-regulated complex system maintaining life on Earth [4]. Such whole system is known with the name of biosphere. Somehow the living and non-living beings evolve together [5, 6], having organisms an influence on their environment [7] and the environment in turn affects the organisms by means of Darwinian natural selection. For instance, photosynthetic organisms regulate global climate, marine microorganisms may be keeping the oceans at a constant salinity and nitrogen-phosphorus concentrations, etc. In agreement with [8] a prerequisite for the coming of the noosphere is the existence of the technosphere. In some way the biosphere is a stable, adaptive and evolving life system with sufficient free energy to power the launching of a technosphere [9]. Therefore, technosphere emerges as a physical environment on Earth being a new layer inhabited by machines, cities and industry with an influence into the biosphere (Fig. 1).

However, and according to the data available today, how realistic is the technological singularity hypothesis? In this essay we present a criticism of Kurzweil's 'Law of Accelerating Returns' focusing on the fact that the exponential growth assumes unlimited resources and energy. Our criticism of Kurzweil's ideas is inspired by computer video games simulating the course of a civilization or a city, e.g. SimCity, and the predictions obtained with simple simulation experiments of population dynamics based on differential equation models.

In this essay we show that if we consider the energy that sustains the noosphere, i.e. Internet, and its growth is simulated by means of an exponential numerical model then it is impossible that our civilization reaches the point of technological singularity in the near future. Our model is based on some fundamental assumptions and simple simulation experiments, obtaining as a plausible scenario what we have called as 'crisis of noosphere'. Assuming that at the present time Internet stores at least 1000 Exabytes (1 Exabyte =  $10^{18}$  bytes) and human knowledge doubling occurs every 12 months, will come a point in the next 50 years (by the year 2063) or maybe before when Internet will consume the total electricity produced worldwide. With current technology this energy would



**Figure 1.** Vernadsky's hypothesis of Gaia states that noosphere (c) is the third layer of development of the Earth, after biosphere (a) and technosphere (b). For Vernadsky noosphere is “the last of many stages in the evolution of the biosphere in geological history”. Teilhard de Chardin states that noosphere is growing towards the Omega point ( $\Omega$ ). Initially the ancient noosphere was very primitive and knowledge was stored in stone or papyrus (d, cuneiform scripts and hieroglyphs), later in paper (e, Gutenberg press) and currently as a global network of computers (f, Internet). Therefore, with the passage of time has changed the information storage media. Now, we must ask the question, is the noosphere energetically sustainable?

be equivalent to the energy produced by 1 500 nuclear power plants. Once this happens there will be a collapse of the noosphere and possibly also from biosphere. Therefore, we believe that with the current technology we are really far from reaching the point of technological singularity.

However, we believe that if a ‘paradigm shift’ occurs first – somewhat like a Cambrian explosion but of technology – then the singularity point could be reached later. Thus, the point of singularity could be achieved with a paradigm shift, namely the design of a noosphere which hardware be adaptable to available energy and designing a more efficient computer machines that the current ones. A systemic model of a noosphere ranging in size according to the available energy is simulated based on Lotka-Volterra equations, assuming that Internet is a *predator* specie that feeds voraciously on a *prey*, the electric power. A hardware architecture with this dynamic behaviour would make it possible to have an Internet being sustained by ‘computer machines’ more effective in terms of power consumption than current ones. And in this respect the Volterra-Lotka model could give us some clues about how the Internet should be designed.

Moreover, we propose the use of non-conventional technologies for the design of a new class of computer-oriented to the implementation of the noosphere. In this essay we speculate about what we have called ‘Nooscomputer’ or *N-computer*, a hypothetical

machine, resembling a Turing machine, but capable of storing and processing human knowledge through emerging computational paradigms, i.e. quantum computation, DNA and Egan's *Permutation City* algorithms. The use of N-computers in data centers would make available a new class of Internet consuming far less power, which would probably help to our civilization to reach the point of technological singularity.

## **IS THE INTERNET THE NERVOUS SYSTEM OF THE NOOSPHERE?**

Noosphere is a term that was introduced by Édouard Le Roy (1870-1954), Vladimir Vernadsky (1863-1945) and Teilhard de Chardin (1881-1955) referring to the sphere of human thought [10]. Edouard Le Roy was the first who used the notion 'noosphere' in a scholarly publication entitled *L'exigence idéaliste et le fait l'évolution* published in 1927. Le Roy wrote [1]:

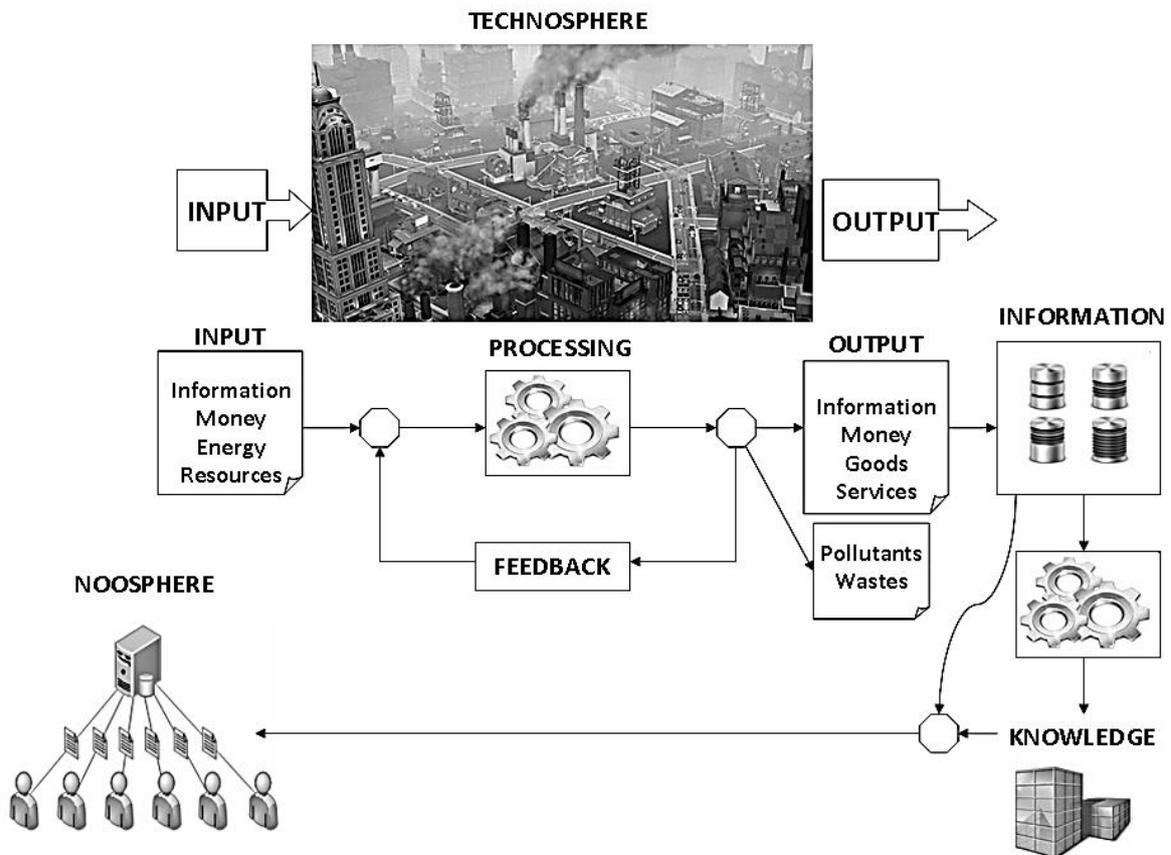
*"Beginning from a man, evolution carried out with new, purely psychic meanings: through the industry, society, language, intellect etc, and thus biosphere transforms into noosphere"*.

However, the explanation of how noosphere arises varies from one thinker to another. The noosphere term was coined by the French theologian and scientist paleontologist Pierre Teilhard de Chardin in 1925 and disseminated in posthumous publications in the 1950's and 1960's. According to Teilhard [11, 12] the noosphere emerges as a result of the interaction among human minds. However, for [8] Vernadsky and although the noosphere is not a material layer it emerges once of human beings sufficiently progress, for example reaching the ability to create new material resources. In the point of view adopted by Teilhard the noosphere will grow up to the point called Omega, the end of history (Fig. 1). For Teilhard the 'Omega point' is the maximum level of complexity and consciousness towards which he believed the universe is evolving. The evolution of humanity toward some ideal situation has received several names, whether Omega point or technological singularity. Now, while the first term has a spiritual meaning the second one has a technological taste. The concept of technological singularity was introduced in the 1950's by John von Neumann [13] who thought that humanity is approaching some a point where once reached would change the course of humanity. At present the singularity advocates predict an explosion of intelligence in which powerful supercomputers and other machines will be well over human skills and intelligence. Among other factors, this explosion of intelligence will result from a dramatic breakthrough in artificial intelligence. So while the concept of Omega point is characteristic of theistic evolutionists, e.g. Francis Collins [14], the concept of technological singularity usually is defended by scientists for whom science promises a limitless evolution of humankind. No matter how this critical point is named, in this essay we will denote it by  $\Omega$ . At present, at the time of writing this paper, there are several predictions of possible dates in which our civilization will reach this point. All the proposed dates have a common feature, whether it is 2045 predicted by Kurzweil or 2030 foreseen by Vinge, in just a few years we will have reached the  $\Omega$  point.

At present, there are several opinions that support the role of Internet as the nervous system of the noosphere. For example, Hagerty [15] thinks that Internet is playing the role of Teilhard's mechanical apparatus of the noosphere. Shenk [16] believes that even when the World Wide Web is a repository for the knowledge of humankind, it is only the beginning of the development of the global mind, and therefore the noosphere. According to Heim [17], Teilhard envisioned the convergence of humans in a single massive noosphere or 'mind sphere', maybe the 'virtual communities' mentioned by McLuhan's global village or Teilhard's Omega point. In accordance with Heim, a thinker and philosopher concerned with virtual reality, we have enriched the process of creating further realities through

virtualization. Taking a step forward in this reasoning and assuming that such virtual realities are ‘windows to the noosphere’ then we arrive to the conclusion that Internet is the hardware of such virtualization.

Now then, how does the noosphere originate from the technosphere? In this essay, we propose the following model. According to Figure 2 technosphere would be an open system since it meets the following characteristics: (i) It is made up of parts that interact with each other, (ii) it is oriented to a purpose, (iii) consumes materials producing a product or service, (iv) consumes energy, (v) interacts, reacts and affects the environment, (vi) it grows, changes and adapts, that is evolves and finally (vii) it competes with other systems, for example with the biosphere. Accordingly as such open system, technosphere would have an *input* (information, money, energy, resources, etc.) and *output* (information, money, goods, services, etc.). The input processing would results in several outputs, including information. The technosphere also produces other undesirable outputs, such pollutants and wastes. Then a part of or all the information obtained can be processed again becoming knowledge. Transforming information into knowledge means that technosphere was able to discover patterns, relationships and trends resulting in formalized and objective contents. Therefore, while the information may be stored in a databases, the knowledge requires more sophisticated media, for example in the knowledge base of an expert system [18]. Another possibility is that the information is forwarded to the input to be processed again. Finally, as the technosphere produces information and knowledge, over and over again, these are embodied in a new entity: the noosphere.



**Figure 2.** A possible explanation of the origins of the noosphere from the technosphere.

## THE ORIGINS OF THE CRISIS: TECHNOSPHERE COMPLEXITY AND ENERGY CONSUMPTION

In accordance with previously described model the noosphere is arising from development of technosphere. This means that the noosphere inherits all the strengths and weaknesses of its predecessor, the technosphere. Consequently, what are the causes of the noosphere crisis? Let us consider the following possible explanation.

Recently Arbesman<sup>1</sup> used *SimCity* -an open-ended city-building computer video game- to measure a city's Kolmogorov complexity. Thus, the complexity of a city could be measured as the shortest algorithm required to reproduce it. Since the technosphere includes the cities of our planet Earth, this method could be used to estimate a minimum value of complexity of the technosphere from the complexity value obtained in the cities. In a theoretical realm, using a small dataset of population sizes and file sizes of some cities constructed with *SimCity 3000*, Arbesman found how complexity linearly scales with population size. Furthermore, it is interesting to note how this result coincides with other similar results obtained with real cities. Bettencourt et al. [19] demonstrated as most aspects of a city, such as electrical use, employment, or population growth, increase linearly based on the city size.

Within the above framework human societies are distinguished by their dominant pattern of energy harvesting, a behaviour which has been called the *energy paradigm* [20, 21]. For example, Garrett [22] modelled the civilization as 'heat engine' because of the need to consume energy. In accordance with this paradigm collapsing civilizations are complex systems that continued to grow beyond the limits of their energy budget. This would be true unless such civilization makes the effort to find an efficient mechanism of technological transition. Therefore, there is a limit to the unlimited growth of the technosphere unless we are able to find a new technology that allows us to build a new technosphere energetically more efficient and therefore energetically sustainable. That is, the 'crisis of noosphere' would be a consequence of the high energy consumption and therefore the noosphere would be inheriting from technosphere this major flaw. Today, Internet – the nervous system of the noosphere – has become a true electric power predator.

## A NUMERICAL MODEL OF NOOSPHERE

Numerical models are mathematical models that use some sort of numerical time-stepping procedure for predicting the system behaviour over time. One application of the numerical models is the study of complex societies as a predictable phenomenon, making predictions according to a mathematical model. Whether using differential [23, 24] or probability theory [25], it is possible to explain from collapse societies such as the Maya civilization to the effects of warfare or some social policies. In fact, some popular computer games, for example *Civilization V*, behave according to some differential equations such as the Malthusian model and simple polynomials of different degrees (ref.: see in Internet the blogs about this game).

In this section and using an exponential (1) or Malthusian growth model [26], we build a simple model (see Appendix, *Scenario 1*) that illustrates what we have called as 'crisis of noosphere':

$$y_1' = k_1 y_1, \quad (1)$$

where  $y_1$  is the amount of information stored in Internet, i.e. the noosphere, and  $k_1$  is the Malthusian parameter, thus the information growth rate.

Based on the reasoning made in the previous section, we will consider the following features about the Internet, the hardware that gives life to the noosphere:

1. Digital information is housed in data centers around the world, doubling in size every 2 years. There are over 500 000 data centers in the world<sup>2</sup>.

Internet and other forms of information technology account for 2 % of all electrical energy used globally. Most data centers that house computer servers rely on non-renewable energy resources, i.e. nuclear and coal-powered energy<sup>2</sup>.

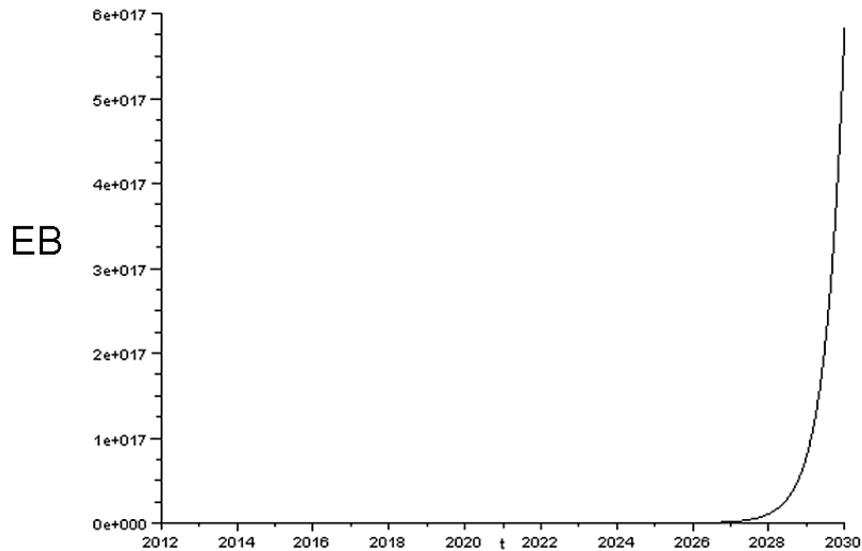
According to estimates made by US industry experts: Internet consumes 30 billion watts or 30 nuclear power stations<sup>3</sup>.

- Moore's law can be applied to the amount of information that people feed into the Internet each day. Only USA stores approximately 898 exabytes (1 EB = 1 000 Petabytes = 1 000 000 Terabytes = 1 billion gigabytes) – nearly a third of the global total information (Western Europe has 19 % and China has 13 %)<sup>4</sup>.

Assuming that digital information housed in data centers is doubling its size every 2 years,  $k_I = 2$ , and setting an initial amount of information  $y_0$  equal to 1000 EB, likely an underestimation of the global actual value, we obtained the results shown in Figure 3:

$$y = y_0 \exp(k_I t). \quad (2)$$

Since to date, 30 nuclear plants represent 2 % of the electrical energy consumed globally, we deduce that by the year 2062 the noosphere will require about 1 500 nuclear power plants, i.e. 100 % of the overall electric energy produced on Earth. According to Figure 3 from the year 2030 the amount of information stored in the noosphere will be around of  $10^{17}$ . This amount of information will have almost doubled the age of the universe ( $10^9$  according to NASA's WMAP Project) and account for 21 % of the number of atoms in the universe ( $10^{78}$ ).



**Figure 3.** Exponential growth of the size of the noosphere (EB) under the assumptions of the “technological singularity” hypothesis.

Is this technology scenario sustainable? Obviously, it doesn't seem that way. According to the excellent essay “The Singularity Myth” [27] written by Theodore Modis<sup>5</sup> there are several reasons why the singularity is not so near. We do not say that it is impossible to achieve in the future, we say that singularity is unattainable with current technology. Among other reasons, the most important are (i) all natural phenomena grow according to the S-curve or logistic function which can be approximated by an exponential or Malthusian model in its early stages. For instance, Modis shows how world population has grown significantly during the 20<sup>th</sup> century depicting an exponential model during early decades which becomes a logistic after World War II. A similar behaviour can be seen with the cumulative oil production in the US and Moore's law, concluding that all exponential natural phenomena will eventually turn into logistics (Modis, 2003) [28]. Therefore, if the exponential is replaced by a logistic or S-curve, what effect will this change have on the predictions made by Kurzweil?

One of the Kurzweil's predictions claims that singularity will be reached by 2045. However, in agreement with our model (ii) by that date and if our civilization continues with current technology, the noosphere will store an amount of information equal to  $4,295 \times 10^{12}$ . On that date the noosphere will consume a 66 % of the overall electric power produced on Earth, i.e. the electrical energy produced by 990 nuclear power plants.

In agreement with Modis (iii) the date on which the singularity is reached will depend to a large extent on the evolution of computing performance. Moreover, we think that the von Neumann architecture, i.e. the design logic behind today's computers, is not the most suitable to manage information and knowledge. For this reason we believe that our civilization will have to face in the near future a *technological transition* resulting in a new kind of computer architecture. Assuming the trend of exponentially growing will continue until 2045 then the computer power will reach  $6 \times 10^{23}$  Flops (floating-point operation per second) or according to Modis and assuming a model of growth in S-curve after 2045 computers will reach a maximum value of  $10^{25}$ . In other words, the computational efficiency of computers will be well below that of Kurzweil's prediction of  $10^{50}$  and above.

The scientific and technological criticisms mentioned previously (i, ii and iii) seem sufficient to justify the need for a technological transition. This technological transition will be a precondition before our civilization can reach the point of singularity. Therefore, so is our civilization today ready for this technological change? At present we know that (iv) technological breakthroughs emerge in a similar manner to the evolution of species, thus according to the punctuated equilibrium principle. This principle introduced by the naturalist Stephen Jay Gould states that speciation occurs in spurts of major changes that punctuate long periods of little change. According to theoretical predictions [28] in the case of technological breakthroughs the future milestones will appear progressively less frequently. In fact, there are thinkers, such is the case of Huebner [29], who argues that the rate of technological innovation is at present decreasing as shown by the fact that the number of patents has been declining since the period 1850-1900.

In short, if we want our civilization to reach the point of singularity in the future, we must previously change the technology that currently supports the noosphere.

## **A SYSTEMIC MODEL OF THE NOOSPHERE**

In this section we will propose an alternative numerical model for the noosphere. Although the model is actually a metaphor, it may help us to find the conditions under which the Internet would be energetically sustainable. Inspired by models in ecology we assume in the model that Internet is a *predator* specie (for example foxes) that feeds voraciously on electric power. Hence, we assume that electrical energy represents the other specie, specifically the *prey* (for example rabbits). The Lotka-Volterra equations (3) [30, 31] arise when the predator  $y_2$ , thus Internet, is related with the prey, the electrical energy  $y_1$ , resulting the coexistence of both species (Fig. 4):

$$\begin{aligned} \dot{y}_1 &= y_1(k_1 - k_3 y_2), \\ \dot{y}_2 &= y_2(-k_2 + k_3 y_1), \end{aligned} \quad (3)$$

where  $k_1$ ,  $k_2$  and  $k_3$  are parameters describing the electric energy production, the loss rate of noosphere (in size) and the interaction (predation rate) of the two 'species', respectively. Equations (3) allow us to have a systemic model of the noosphere since this model shares some features with other phenomena in which the equations have been applied, e.g. predator-prey interactions, in the theory of autocatalytic chemical reactions as well as in economic theory and modelling historical civilizations [23]. However, since this model is a metaphor, indeed a thinkertoy, it is assumed that the size of the noosphere varies (e.g. EB,

number of data centers, servers etc.). Of course, the variable size of the noosphere is an Internet feature that should be included in the future to make Internet energetically sustainable. That is, its size varies according to the increasing or decreasing of the amount of electrical power available on Earth. Also we assume that the amount of electric energy is measured, e.g. as number of nuclear power plants, by varying the number of nuclear plants according to the size of the noosphere. Using the model (3) and setting up parameter values and initial conditions (see Appendix, *Scenario 2*) we illustrate a plausible systemic model of the noosphere (Fig. 5).

Following, we propose an alternative model in which the electrical energy equation is modified according to what is known as the energy paradigm. In agreement with Karakatsanis [21] the dynamics of an energy paradigm could be expressed by the following equation:

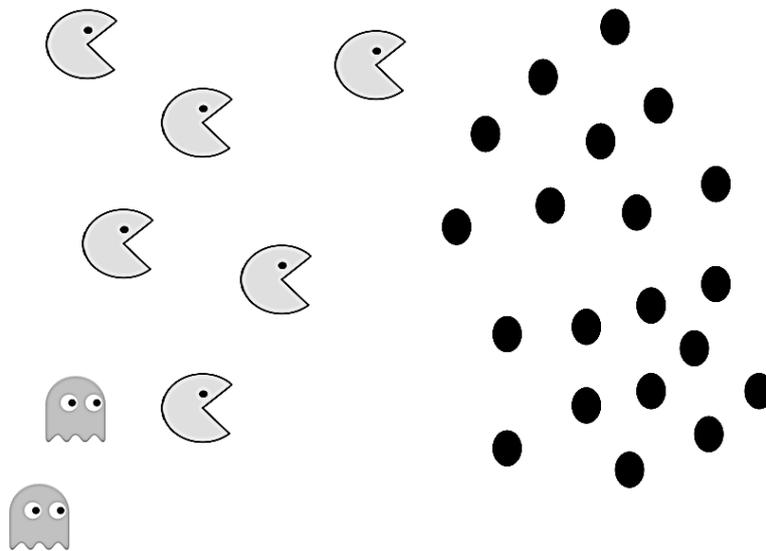
$$y_1(t) = \varepsilon_t y_1(t-1) - \frac{(1-\alpha)\varepsilon_t}{A} y_1^2(t-1). \quad (4)$$

In equation (4) the ratios between the parameters  $\varepsilon$ ,  $\alpha$  and  $A$  define the model dynamics. Inspired by (4) we included  $k_4 y_1^2$  term in the first equation of the Lotka-Volterra model (3).

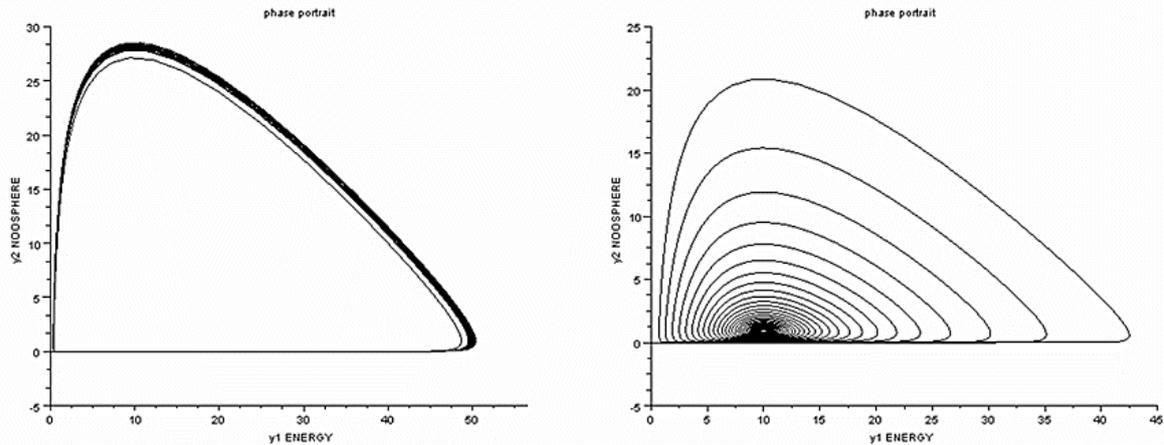
Using this modification it is possible to simulate a civilization, for example our civilization, evolving its energy consumption policy under the threat of energy depletion:

$$\begin{aligned} y_1' &= y_1(k_1 - k_3 y_2) - k_4 y_1^2, \\ y_2' &= y_2(-k_2 + k_3 y_1), \end{aligned} \quad (5)$$

Based on these new expressions we can simulate a new scenario for the noosphere (see Appendix, *Scenario 3*) under the influence of so-called energy paradigm. In the model (5)  $k_4$  is the resource depletion pressure, i.e. electric energy.



**Figure 4.** ‘Pacman game’ without ghosts (they eat the Pacs) is a good metaphor for a systemic model of the noosphere (the dots represent the energy/prey, the Pac represents Internet/predator). In this case the number of Pacs and dots available could coexist in equilibrium according to a Volterra-Lotka model.



**Figure 5.** Cycles solution for coexistence between noosphere and electrical energy. Left(right) graph shows *Scenario 2* (*Scenario 3*).

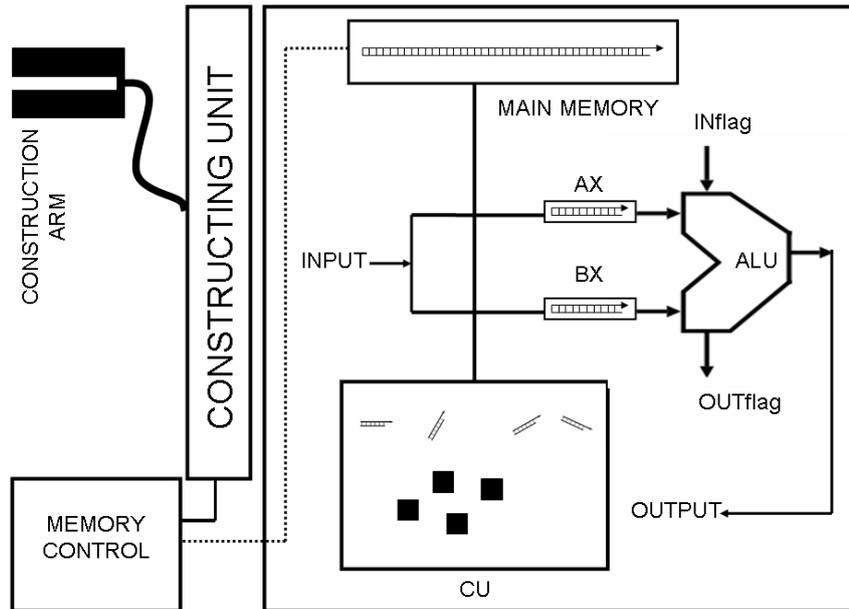
## BUT IS THERE ANY CHANCE OF GETTING TO THE $\Omega$ POINT? THINKING ABOUT N-COMPUTERS

As referred to in the introduction in this essay we speculate about *N-computers*, an abbreviation for 'Nooscomputer', thus a hypothetical machine resembling a Turing machine but capable of storing and processing human knowledge. At present such machine could be imagined as a result of very diverse technologies, namely through quantum computation [32], DNA and Egan's *Permutation City* algorithms. One goal in this essay is to give some highly speculative solution to criticisms that we discussed earlier.

The use of N-computers in data centers would have two advantages. On one side, future generations will have a new class of Internet with (i) electric power *consumption* well below the current one, on the other hand an Internet designed according to a (ii) *scalable architecture*, i.e. the number of servers would increase or decrease depending on knowledge storage needs and electric power availability.

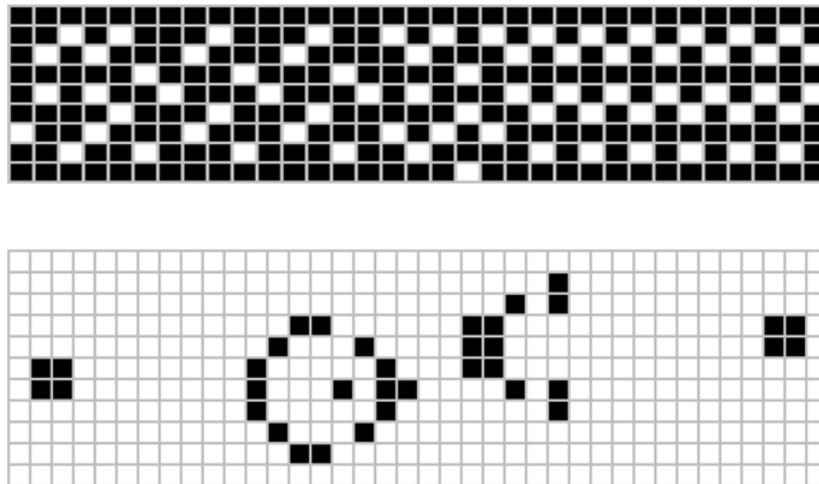
Figure 6 shows a sketch of the elements and logical organization of an N-computer. At right, and inside of a box, the sketch shows the main memory, control unit (CU), registers (AX, BX) and the arithmetic logic unit (ALU). Although in principle this architecture is similar to the current computers based on von Neumann architecture, our proposal varies significantly by the 'hardware' from which elements are made. For example, while main memory is DNA, the ALU operates based on cellular automata. Thus, the microprocessor is a cellular automata engine combined with DNA-based computing. On the left, the figure shows how the N-computer is provided with a von Neumann self-replicating automaton<sup>6</sup>. This automaton would allow the self-replication of N-computer like a 'predator specie' growing Internet, and therefore the noosphere, according to Volterra-Lotka model. Thus, while a significant portion of the DNA memory is dedicated to storing knowledge, a small portion of DNA is devoted to encode the information for self-replicating a copy of the N-computer. Of course, an N-computer also can be 'killed', i.e. shutdown, if required by the Volterra-Lotka dynamics.

In 2012 Church et al. [33] stored a few petabytes ( $10^{15}$ ) in a single gram of DNA. They encode one bit per base: adenine (A) or cytosine (C) for zero, guanine (G) or thymine (T) for one, synthesizing strands of DNA that stored 96 bits. In order to read the data stored in DNA the sequence of bases (A, T, G, and C) is translated to a binary string. Each strand of DNA has a 19-bit address sequence playing the role of a memory address. One of the most interesting features of the 'DNA memory' is its great stability. Nearly a year after this finding



**Figure 6.** *N*-computer architecture. In the ‘Pacman game’ in Figure 4 each Pac would have a skeleton as shown in this sketch.

Goldman et al. [34] were able of encoding all 154 of Shakespeare’s sonnets in DNA, 26-second audio clip from Martin Luther King’s famous “I have a dream” speech and a copy of James Watson and Francis Crick’s classic paper on the structure of DNA.



**Figure 7.** Garden of Eden (top) and spacefiller (bottom) configurations.

Based on previous experiments we envision *N*-computer main memory implemented with DNA strands. Registers (labelled in the sketch as AX and BX, obviously *N*-computers can have more than two) implemented too with small DNA memories while the CU is built by a mixture of DNA and enzymes<sup>7</sup>. The CU performs very different functions, either converting a DNA sequence to binary, the inverse operation, or such as a search engine (maybe a version of Google but at molecular level or ‘Moolgle’) identifying certain sequences in the DNA strand. CU also controls which DNA sequences are read, written or deleted, ruling an important mission: CU includes the molecular machinery necessary for DNA replication. The latter task is required when von Neumann self-replicating automaton comes into operation resulting in one or more *N*-computer ‘children’.

Consider the following example. If a DNA sequence is TATAGCCG storing some knowledge about the Roman Empire, establishing that subunits T and G are equal to 1 and adenine A and C are equal to 0, then CU transforms this sequence to 10101001. This binary sequence is temporarily stored in the AX register and defines the initial state of the cellular automaton in the ALU. Applying this procedure, the N-computer can perform the processing of knowledge, conduct operations with the knowledge stored in the DNA, e.g. change data, delete data, relate two DNA sequences storing related knowledge, etc.

So how can we implement the ALU on this new computer? In 1994 Greg Egan wrote *Permutation City* [37], a hard-core science fiction novel that explores a model of consciousness and reality. Despite being a science fiction novel the computational paradigm that underlies is extremely interesting and suggestive. The author assumes that consciousness is Turing computable and consequently it could be simulated by a computer program. Although it is a science fiction novel, in reality the idea is not so far-fetched. In the 1990's Roger Penrose and Stuart Hameroff [38] proposed that consciousness takes place within neurons in structures called microtubules. Recently, Alfonseca et al. [39] were able to simulate with a new class of cellular automata, the mechanism at cellular level that could support consciousness according to the Hameroff-Penrose hypothesis. Our model was based on a new class of hybrid cellular automata (QvN), capable of performing as either a quantum cellular automata (QCA) or as a classical von Neumann automata (CA). In the simulation experiments we showed how the mechanisms conjectured in the Hameroff-Penrose hypothesis could take place in the microtubules. Thus, how classical von Neumann automata states leads to emergence of quantum coherent superposition, taking place transitions between the quantum and classical worlds. According with this hypothesis some high level brain faculties, e.g. consciousness, occur in the transitions from quantum steps to classical ones. Therefore, consciousness could be computed with a very simple machine which is restricted to a few simple operations, named Turing machine. In addition it is also assumed that it is possible to "copy" the consciousness of a human brain, "living" these copies or brain emulations as objects in a virtual reality (VR) environment. From these assumptions a VR city is created, *Permutation City*. In this VR environment copies are the only objects simulated in full detail, while the remainder of the objects are simulated with varying the rendering grain, using lossy compression and hashing algorithms<sup>8</sup>. At one point the Egan's novel explains that the city is a fragment of a Garden of Eden<sup>9</sup>, configuration of an expanding massively cellular automata [18, 40] universe known in this fiction as TVC (Turing, von Neumann, Chiang). Since Garden of Eden configurations can only be obtained if the simulation has been designed for this purpose by an intelligent being, then this configuration is used as clue to show that a copy is 'living' in a simulated world. However, and this is the scientifically interesting aspect of the novel, this cellular automata universe has properties that make it similar to the *spacefiller* configuration in Conway's Game of Life<sup>10</sup>. Consequently, taking inspiration from this novel we could design and build the ALU of N-computers.

In an N-computer we replace consciousness by knowledge. An important feature of this change is that whereas it is assumed that consciousness is not computable [38], although the mechanism that generates it may be, and therefore cannot be simulated by a Turing machine as in the Egan's novel, knowledge is computable and therefore treatable with a Turing machine. An example of the latter are expert systems [18]. Since the binary sequences representing some knowledge, e.g. 10101001, are the *input* data or initial cellular automata configuration of the ALU, it seems appropriate that ALU performs operations based on something similar to some configurations found in Conway's Game of Life. This procedure is what we call in this essay as *Egan's algorithm*. Finally, the *output* will be the final state of the automata (at equilibrium, or at a given iteration, etc.) which can be transformed from a binary code (0s and 1s) to a DNA sequence of A, T, G and C.

One of the hard problems to be solved on the N-computers is their construction. Although this is surprising some authors have been able to combine DNA, quantum computing and cellular automata in the same recipe [41] getting to know this cocktail as the *femtocomputing* paradigm. De Garis [42] shows theoretically how the properties of quarks and gluons can be used to perform computation at the femtometer (i.e.  $10^{-15}$  meter) scale. Therefore, an N-computer could be build using non-standard hardware, thus with unconventional computational hardware.

## CONCLUSIONS

In 1962 Arthur C. Clarke wrote the novel *Profiles of the Future: An Inquiry Into the Limits of the Possible*, writing the following thought:

“Any sufficiently advanced technology is indistinguishable from magic.”

Thirty-two years later Greg Egan wrote *Permutation City*, stating in the novel:

“computers aren’t made out of matter.”

At present human beings from most developed countries own smart phones, laptops, tablets and other inventions with which they communicate with other humans or receive information on news, weather or predictions about the stock market. All these gadgets use to communicate with each other and feed on the invisible layer that stores the information and knowledge, the noosphere. The speed of communication and the fact that the complex mechanisms that enable this technology are not transparent to the user, have led to a false impression that these inventions are a kind of magic. However, and for the same reason that genetic information requires a material substrate, DNA, the noosphere and all the gadgets that live in the noosphere, also require a substrate, Internet. With current technology, Internet has become a true electric power predator and it is for this reason that we see difficult to achieve in a few decades the  $\Omega$  point. Obviously, when thinkers like Teilhard de Chardin introduce the idea of an omega point, his idea is spiritual and has nothing to do with a still non-existent Internet or cyberspace [43].

In accordance with our reasoning, if we ignore the energy paradigm then we will easily fall into the trap of assuming exponential models of resources, energy and space available, which are not unlimited. A simple model like the one we have called *Scenario 1* is crumbling down when we consider the energy consumption, concluding that in the future the noosphere will not be sustainable. Also in this essay we discussed other minor criticisms (*i*, ..., *iv*) to the hypothesis of singularity, taken from studies conducted by other thinkers. Our position does not deny the possibility of reaching  $\Omega$  point, quite the contrary we propose that this would be possible but only if we are able to redesign the hardware with which the noosphere acquires material form. A systemic model of the noosphere as simulated in *Scenario 2*, shows the possibility of a balance between the size of the noosphere and the available electrical power. Moreover, in *Scenario 3* we have shown how this equilibrium is even possible under the moderate effects of the energy paradigm. Finally, the idea of N-computer is highly speculative but has the purpose of provoking a mental brainstorm that allows us to find a new computer design more efficient and oriented not only to information management but also knowledge. Internet, evolution, consciousness and noosphere are interrelated concepts [44]. Now, as important as the meaning of such concepts is the hardware in which such concepts acquire their material form. In this context and under the perspective of sustainability, despite all the criticism and arguments made, the main question remains open: when our civilization will reach the  $\Omega$  point or singularity?

## REMARKS

<sup>1</sup>See S. Arbesman. 2012. *The mathematical puzzle that is the complexity of the city.* <http://www.theatlanticcities.com/politics/2012/06/mathematical-puzzle-complexity-city/2261>.

<sup>2</sup>See C. Keenan. 2011. *How much energy does the Internet consume?* <http://planetsave.com/2011/10/27/how-much-energy-does-the-internet-consume>.

<sup>3</sup>See M. Tyson. 2012. *The Internet uses 30 nuclear power station's energy output.* <http://hexus.net/tech/news/industry/45689-the-internet-uses-30-nuclear-power-stations-energy-output>.

<sup>4</sup>See S. Forman. 2013. *The US is home to one third of the world's data – here's who's storing it.* <http://qz.com/104868/the-us-is-home-to-one-third-of-the-worlds-data-heres-whos-storing-it>. In reference to this matter, see Gantz, J.F., ed.: *The Diverse and Exploding Digital Universe*. An IDC White paper, 2008.

<sup>5</sup>Modis, T.: *The singularity myth.* [http://www.growth-dynamics.com/articles/Kurzweil.htm#\\_ftn1](http://www.growth-dynamics.com/articles/Kurzweil.htm#_ftn1), 2006.

<sup>6</sup>It is a self-replicating machine designed by John von Neumann. Using a construction arm or a writing head the machine can construct or print out a new copy of itself. The sequence of operations to be performed by the machine are encoded into a 'tape', i.e. DNA memory. A very interesting idea relating this self-reproducing automaton (universal constructor) with the ALU automata depicted in Figure 7 (top), is the existence of Garden of Eden configurations. However, we will not explain here this notion to be outside the scope of this essay.

<sup>7</sup>Enzymes are proteins that catalyzes a chemical reaction transforming a molecule or substrate to a new molecule or product [35, 36].

<sup>8</sup>Lossy compression algorithms are multimedia data encoding methods (audio, video, images), e.g. JPEG, MP3. Hash functions are procedures for transforming data of variable length to data of a fixed length, e.g. using <http://www.fileformat.info/tool/hash.htm> we transformed the text *Singularity hypothesis* to MD5 `a51129b92a02a1f932e63ce0ea586381`.

<sup>9</sup>It is a cellular automata pattern or configuration that has no parents or a predecessor configuration. For instance, in the *Game of Life* the pattern depicted in Figure 7 (top).

<sup>10</sup>It is a cellular automata introduced by John Horton Conway in 1970. Once initial configuration is created (the only input), the player only observes its subsequent evolution. Each cell in the grid can be live (state 1) or dead (state 0). A live cell with two or three live neighbors stays alive and has a neighborhood consisting of the eight cells. The state of the cells is updated according to the following rules: (i) A dead cell (0) with 3 live neighbours becomes a live cell (1); (ii) a live cell (1) with 2 or 3 live neighbours stays alive (1); (iii) in all other cases, a cell dies or remains dead (0). A spacefiller is any pattern that grows at a quadratic rate by filling space with a periodic configuration in both space and time. For instance, in the *Game of Life* the pattern depicted in Figure 7 (bottom).

## APPENDIX

The numerical model simulations were conducted on Scilab 5.4.1 environment [45].

### Scenario 1

```
//Noosphere equations
```

```
//Exponential model
```

```
function [w] = f(t,y)
```

```
w(1) = y(1)*k1;
```

```
endfunction
```

```
k1 =2;
```

```
t0 = 0; y0 = [1000];
```

```
t = [0:0.01:17];
```

```

y = ode(y0,t0,t,f);
xset('window',1)
y1 = y(1,:);
clf;
plot2d(t+2013,y1,style=1);
xlabel('Noosphere collapse','t','EXABYTES');
//end script

```

### Scenario 2

```

//Lotka-Volterra equations
//y1 = prey-energy population, y2 = predator-noosphere population
//dy1/dt = y1*(k1-k3*y2), dy2/dt = y2*(-k2+k3*y1)
//Use k1 = 1, k2 = 10, k3 = 1 for 0 < t < 100
//y1(0) = 30, y2(0) = 80
function [w] = f(t,y)
w(1) = y(1)*( k1-k3*y(2));
w(2) = y(2)*(-k2+k3*y(1));
endfunction
k1 = 1; k2 = 10; k3 = 1;
t0 = 0; y0 = [0.02;1];
t = [0:0.01:100];
y = ode(y0,t0,t,f);
y1 = y(1,:); y2 = y(2,:);
mtlb_subplot(2,2,1);plot2d(t,y1);xlabel('Energy','t','y1');
mtlb_subplot(2,2,2);plot2d(t,y2);xlabel('Noosphere population','t','y2');
mtlb_subplot(2,2,3);
plot2d(y1,y2);xlabel('phase portrait','y1 ENERGY','y2 NOOSPHERE');
//end script

```

### Scenario 3

```

//Lotka-Volterra equations under Energy Paradigm dynamics
//y1 = prey-energy population, y2 = predator-noosphere population
//dy1/dt = y1*(b-c*y2), dy2/dt = y2*(-d+c*y1)
//Use k1 = 1, k2 = 10, k3 = 1 for 0 < t < 100
//y1(0) = 30, y2(0) = 80
function [w] = f(t,y)
w(1) = y(1)*( k1-k3*y(2))- 0.01 * y(1)^2;
w(2) = y(2)*(-k2+k3*y(1));
endfunction
k1 = 1; k2 = 10; k3 = 1;
t0 = 0; y0 = [0.02;1];
t = [0:0.01:100];
y = ode(y0,t0,t,f);
y1 = y(1,:); y2 = y(2,:);
clf
mtlb_subplot(2,2,1);plot2d(t,y1);xlabel('Energy','t','y1 ENERGY');
mtlb_subplot(2,2,2);plot2d(t,y2);xlabel('Noosphere','t','y2 NOOSPHERE');
mtlb_subplot(2,2,3);
plot2d(y1,y2);xlabel('phase portrait','y1 ENERGY','y2 NOOSPHERE');
//end script

```

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# TOWARDS IMMERSIVE DESIGNING OF PRODUCTION PROCESSES USING VIRTUAL REALITY TECHNIQUES

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## ABSTRACT

The article provides a novel approach to the implementation of virtual reality within planning and design of manual processes and systems. The use of hardware and software required to perform different production – especially assembly – tasks in a virtual environment, using CAD parts as interactive elements, is presented. Considering the CAD parts, the format conversion problem is comprehensively described and solved using format conversion software to overcome the present poor data connectivity between the CAD system and virtual reality hardware and software. Two examples of work processes have been made in a virtual environment: peg-in-hole and wall socket assembly. In the latter case, the traditional planning approach of manual assembly tasks using predetermined motion time system MTM-2 has been compared with a modern approach in which the assembly task is fully performed within a virtual environment. The comparison comprises a discussion on the assembly task execution times. In addition, general and specific advantages and disadvantages that arise in the immersive designing of production processes using virtual reality are presented, as well as reflections on teamwork and collaborative man-machine work. Finally, novel technologies are proposed to overcome the main problems that occur when implementing virtual reality, such as time-consuming scene defining or tedious CAD software data conversion.

## KEYWORDS

virtual reality, assembly planning, human-computer interaction, concurrent engineering, MTM

## CLASSIFICATION

ACM: B.4.2, C.3, C.5.m, D.2.6, H.1.2, H.2.m, H.5.2, I.2.10, I.3.8, I.4.9, I.6.3, I.6.4, I.6.5, I.6.7, J.2, J.6, M.4  
JEL: O30, O35

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## **INTRODUCTION**

Virtual reality (VR) is a computer-generated interface that imitates reality and allows user interaction in that imaginative world by specific interaction devices such as head mounted displays, haptic gloves, motion trackers and sensors. A key element of a created interface is interaction. A special impact of VR can be foreseen regarding further exploitation of human mental and motor sensing in work processes [1]. Thanks to the interaction devices, it is possible to interact with different objects within VR which help in carrying out different types of work or production processes. In the past, VR devices were rare, and researchers were forced to make special type of device that could deal with VR content since commercial VR devices were not available as they are today (e.g. Oculus and HTC Vive). Regardless of these limiting circumstances, a lot of quality research is done in the field of virtual assembly, virtual prototyping and virtual manufacturing. De Sa and Zachmann [2] investigated the steps needed to apply VR for virtual prototyping to verify assembly and maintenance processes in automotive and aerospace industries. Such processes are also applicable for shipbuilding or any other industry and even services. Further, manufacturing can also be observed and improved using modern VR techniques: Iwata et al. [3] stated that “virtual manufacturing is defined as a computer system which is capable of generating information about the structure, status, and behaviour of a manufacturing system as can be observed in a real manufacturing environment.” So, “VR holds great potential in manufacturing applications to solve problems before being employed in practical manufacturing, thereby preventing costly mistakes.” [4]. Boothroyd and Dewhurst [5] revealed a long ago that “the assembly process often drives the majority of the cost of a product”, what makes research in this area constantly important. Thus, VR is applicable for design and analysis of human work and activities in manufacturing and production, but generally and moreover, for all processes, industries and services which include some kind of human labour. In the case of very complex products such as ships, there is a big database of 3D models with a huge amount of data. VR can help to manage and visualise model lot easier using supporting VR prototyping and is therefore widely used in early design phases (concept design), simulations and training methods [6] that can enhance the overall experience to overcome the negativity of physical models. And finally, immersification of a process by VR, eventually and gradually leads to a fully automatic process.

When it comes to process design and human resource planning, various empirical methods, as well as the concurrent engineering (CE), yielded results that showed the importance of training in achieving higher performance [7]. Virtual training can be very easily accomplished in a virtual environment that is by itself safe and without a possibility of hurting workers. As an example, in the field of the shipbuilding industry, VR is applied in the study of the escape routes or army crew training in the vessels like submarines where problems with lack of evacuation space exist: “Simulation is the other important activity where jobs like painting and welding are known to be difficult and one of the most important processes in ship construction. These processes are cost-effective and also directly related to the quality of the ship under construction. So, it is particularly important to train workers so that they can paint evenly on large surfaces with a uniform thickness and [that] they can weld properly too.” [8]. Further, Smith [9] believes that “concurrent engineering can be seen as a summary of best practice in product development.” Helander et al. [10] concluded that “the trend toward global manufacturing and geographically distributed work appear to be shaped by the consumer demand for more individualized products and a more direct connection between the customer, designer and manufacturer.” When constructing the large-scale products such as a ship or any other vessel, where construction offices are often not located at the same place, the connection of all types of people involved in developing process can be

very cost effective. Using VR techniques, the connection between the customer, designer and manufacturer is easier to achieve, even without physical presence. The advantage of 3D immersive visualisation of the ship in an immersive environment is the “ability to have geographically distributed participants sharing space with each other and the objects under discussion. This allows the different participants to point at specific objects in the scene or set the parameters of the simulation to specific values to clarify the information. It gives the users a common context for their discussions, especially in international collaborations.” [8].

Except in the field of virtual training and virtual design, VR techniques can further significantly enhance the existing processes through their virtual process planning. In addition to manufacturing and production, the potential of virtual process planning is recognised in medical [11] and dental [12] services.

The unavoidable term implied by VR is immersion. The concept of immersion comprises generating of a 3D virtual reality image that appears to surround the user, where the image is generated through a computer screen or system. The sense of immersion can vary from non-immersive VR to fully immersive VR. With regard to the levels, VR has recently been divided into a non-immersive, semi-immersive and fully immersive virtual reality [13]. However, due to the newly presence of commercial versions of VR systems, the situation changes and the level of semi-immersive virtual reality is practically lost. Therefore, the new division of VR could only be done in two categories: non-immersive and fully immersive virtual reality. Table 1 shows the differences between these two levels.

**Table 1.** Levels of virtual reality.

Level	Input devices	Output devices	Resolution	Sense of immersion	Interaction	Price
Non-immersive	Mice, keyboards, joysticks and trackballs	Standard high resolution displays, multiple displays, projector screens	High	None or low	Low	Low cost VR systems
Fully immersive	Haptic/motion tracking/motion recognition devices, voice commands	Head mounted display	Medium	High	High	Medium cost VR systems

VR has an increasing importance in product design and process and system planning. It is about the use of an immersive – powerful interactive tool, which includes visualisation and haptics for simulation – consideration and evaluation of previously faithfully crafted constructs in an equally faithful environment. VR thus enables better design results; so, on the one hand, it is a natural technological development of design activities, while on the other hand it involves the evaluation and verification of traditional design approaches and methods. Furthermore, even the entire plant can be simulated in a virtual environment. Factory simulation for immersive investigation has been presented by [14], and although no direct manipulation of objects is possible, VR produced quality results and earlier identification of problems than when using conventional simulations. In industry, the competition is challenging and new methods and enhancements need to be developed fast. To keep the track with the competition, novel technologies must be implemented as soon as possible, immediately when their efficiency is approved. From all the aforementioned, it is evident that the VR provides a unique approach to problem solving, especially in the area of designing of product and work processes. Moreover, software packages have been developed for virtual

applications in manufacturing (e.g. CATIA/DELMIA, Siemens NX). For example, according to [4]: “DELMIA package provides authoring applications that can be used to develop and create virtual manufacturing environment to address process planning, cost estimation, factory layout, ergonomics, robotics, machining, inspection, factory simulation, and production management.” Likewise, Siemens NX software is an integrated product design (CAD), engineering (CAE) and manufacturing (CAM) solution that helps deliver better products faster and more efficiently. In the field of shipbuilding, FVIEWER VR software developed by SENER and fully integrated into FORAN environment gives the user a possibility to review the ship 3D model, detect collisions, walk through and interrogate with the model, measure clearances, make annotations and many other features [8].

However, apart from the mentioned above, VR is generally still not satisfactory represented in various CAx software packages: despite the advances regarding the nearer past, when the user of VR systems “in spite of using some immersive visualisation tools, e.g. head-mounted display (HMD) with tracking technology and VR gloves, does not perceive an artificial computer world as real, because while interacting with any VE object it is not possible to feel the interaction with gravity (and other) forces and inertia of mass-objects” [15].

To change that, bimanual haptic interaction backed by powerful hardware and software tools should be used, as proposed: “Considering the importance of bimanual interaction in real life, not using both of our hands could lead to a loss of efficiency or immersion for a certain number of tasks. ... Haptics can greatly enhance the immersion of a user into a simulated or remote environment by stimulating the tactile and proprioceptive senses” [16]. Not including haptic devices will result in limiting environment due to the lack of force feedback which is extremely important in the most assembly operations.

This paper will focus on creating a virtual work environment as realistic as possible, without haptic devices, and it is based on the research conducted in [17]: Manual assembly task analysis may be performed using Oculus Rift DK2 HMD and Leap Motion Controller, with bimanual interaction with objects in the environment. Designing of manual production or work processes, especially in large-scale production like shipbuilding where thousands of parts should be assembled, significantly contribute to the overall costs of a product and therefore should be carefully developed, measured and evaluated. For manual assembly task analysis, tools like predetermined motion time system MTM (Methods-Time Measurement), are nowadays traditionally established in the industry, enabling description, design, evaluation and improvement of human manual work. MTM is based on subdividing of a worker’s manual operations into basic motions such as GET, PUT, REGRASP etc. that have corresponding – predetermined and standard execution times. Thus, while many supporting tools are available for production planning (e.g. Tecnomatix Plant Simulation or visTABLE), there is no such support for planning manual work using VR. The results of VR assembly planning and classic assembly planning using the system MTM-2 (one of the versions of the MTM system) will be compared on the basis of wall socket assembly task [18]. Recently, new methods to improve the traditional approach to MTM system with support for real walking was implemented [19].

## **CONNECTING CAD AND VR**

VR techniques can lead to enhancement and improvement of existing processes and services, especially in environments where interaction between human and system elements is important. As the techniques of VR have an increasing significance, it is most likely that the new principles and advantages that the virtual environment can provide will result with even broader use of VR techniques. Apart from the application in the areas of assembly of components, quality control, virtual plant simulations and virtual training tasks, many other

studies are conducted on this subject. The interaction elements in created virtual environment will be parts generated in CAD software. The realisation of connecting CAD and VR system is relatively new because commercial VR systems came to the market only a few months ago. On the other hand, CAD systems like CATIA were developed decades ago and even such newer systems are still relatively old in comparison with novice VR technology. Due to all of the above, it can be expected that interaction between CAD and VR will result in numerous problems such as incompatibility and lack of mutual support. However, format conversion issue existed in the near past, when it was more complex to show CAD file on VR platform using VRML. Although there are certain improvements, the problem remains the same. As de Sa and Zachmann [2] concluded, “to avoid that designers have to become familiar with different software tools, the number of interfaces must be kept low. To achieve that the two worlds need to be integrated, at least to a higher degree than present today.” Also, they emphasised that “VR will not become a widespread tool in manufacturing industries before it is seamlessly and completely integrated into the existing CAx and IT infrastructure.”

In order to connect CAD geometry and VR platforms such as low-budget Google Cardboard or Oculus Rift, it is necessary to adapt the output geometry of the CAD part to a particular type of software that allows creating a virtual environment for selected platforms. Considering intuitive and user-friendly interface, the development software that will be used in this work is Unity3D. Apart from the Unity3D, other 3D game engine software such as CryEngine or Unreal could have been used to create a virtual environment in which the following tasks would be performed. However, using other engine would result in different procedures and setup parameters to define the environment, so the most convenient software to use in this project was shown to be Unity3D.

Unity3D is the game engine and has support for more than 20 different platforms. The software has direct support for recognising formats .FBX, .dae, .3DS, .dxf and .obj. Since conventional CAD software does not provide the ability to save output geometry in any of the before mentioned formats, a format converter will be used to achieve the desired compatibility between CAD parts and VR systems. The most convenient software for format conversion is Autodesk 3DS Max, with the ability to import various file formats, such as .CATPart & .CATProduct (CATIA), SLDPRT & SLDASM (SolidWorks), PRT & ASM (ProE) but also for universal formats like STEP or IGES. The ability to import nearly all types of formats from the most widely used CAD software allows to save and export desired geometry in a format supported by Unity3D (Fig. 1). After format conversion, to display the crankshaft on the Google Cardboard platform (Fig. 2), there are several additional things that should be done, in terms of software installation, settings and programming.

Incorporating CAD geometry into virtual environment provides 3D immersive experience, easier visualisation and creation of an impression of reality, but also the ability to scale objects, where objects of bulky dimensions can be reduced, resulting in easier imagery and manipulation of parts. However, without including advanced interaction devices into a virtual environment, the user has no ability to move or interact with objects because they are static. For the objects to be dynamic, intensive programming work should be done for each individual object (if there are different movement rules between objects), resulting in time consumption and limiting environment. Also, it is important to use scripts to define behaviour, the functionality of objects and more complicated interactions and relationships between them [15]. Due to the disadvantages of displaying content on the Google Cardboard platform, the Oculus DK2 platform will be used. Oculus provides a number of advantages primarily in terms of the quality and reality of virtual visualisation compared to the mobile platform. Also, Oculus uses computer resources to display content directly, unlike Cardboard, where smartphone resources are used, which significantly deviate from the computer component's performance.

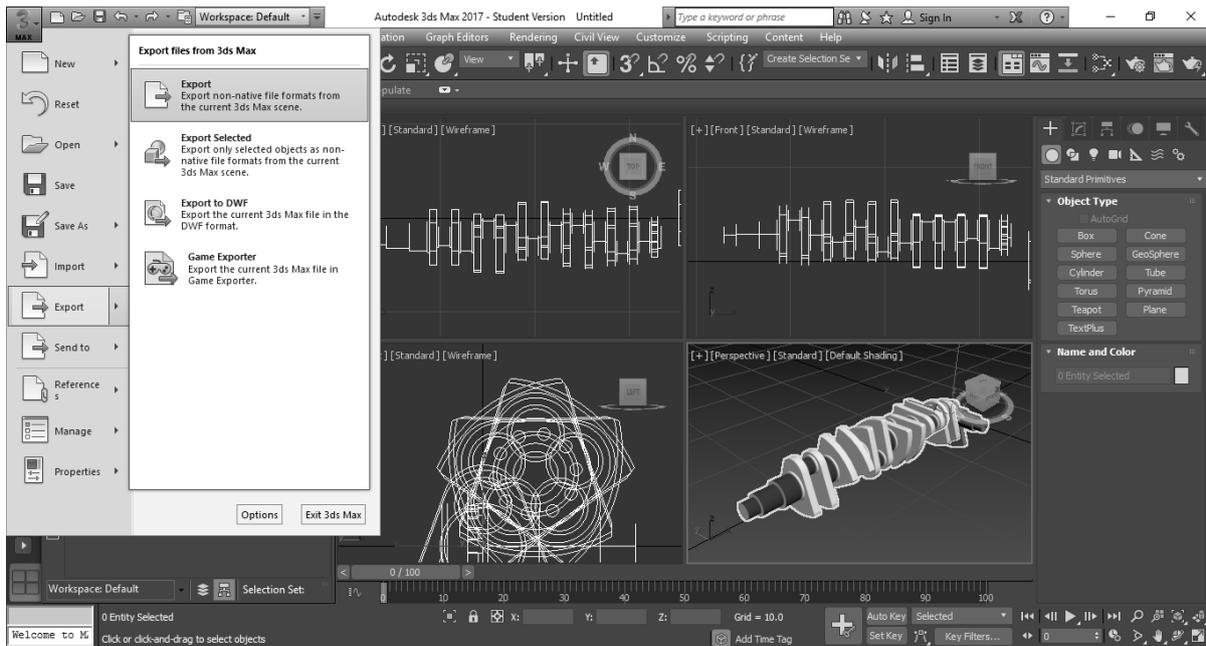


Figure 1. Format conversion on part crankshaft in the software Autodesk 3DS Max.

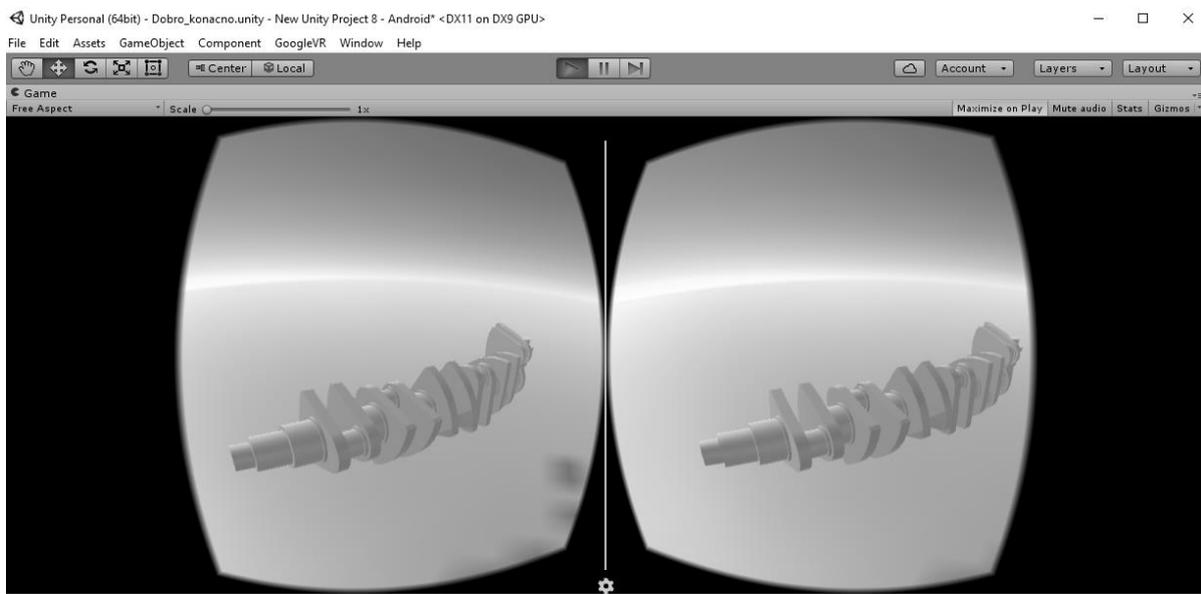


Figure 2. Crankshaft displayed in Unity3D (Cardboard view).

By means of Oculus Rift and Leap Motion Controller a user is able to interact and manipulate with parts. The procedure of format conversion remains the same, with the only difference in different build platform which is in this example Windows (The other platforms are: Mac, Linux, Android, iOS etc.).

## PROCESS DESIGN USING VR

In a virtual environment, peg-in-hole and assembly of wall socket tasks will be solved using Oculus Rift and Leap Motion Controller (Fig. 3). In the example of the assembly of the wall socket, the task execution time in the virtual environment will be measured and then compared with the results of a traditional planning approach which uses predetermined motion time system MTM-2.

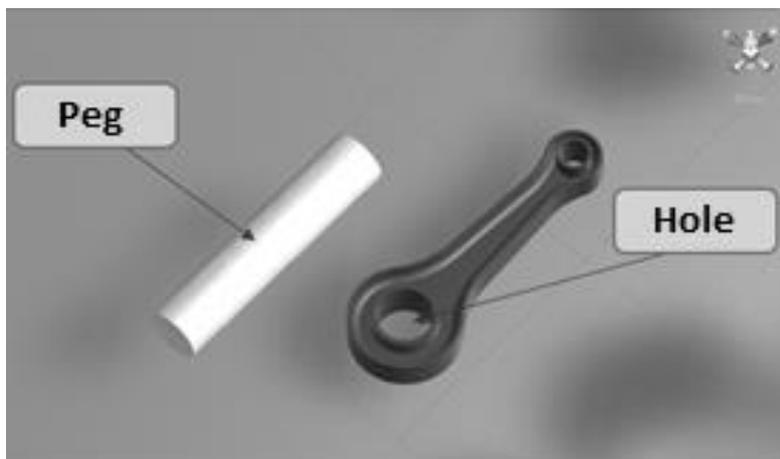


**Figure 3.** Experimental work environment for virtual solving of assembly tasks.

### PEG-IN-HOLE

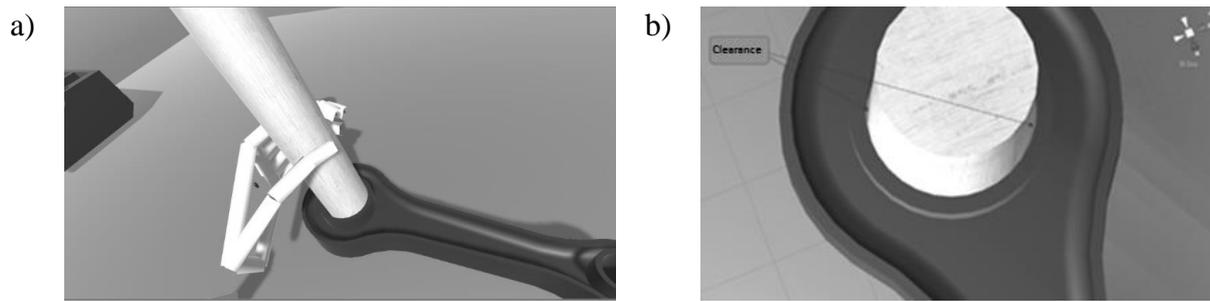
Peg-in-hole still remains as one of the major problems in part assembly processes, regardless of whether the parts are assembled manually by human hand or automatically by a robot. Numerous studies have been carried out in this area (e.g. [20]), but solving peg-in-hole task in virtual environment actualises this problem yet again.

In order to successfully complete the assembly task, several actions are required: 1. Locate the peg and hole in virtual environment (Fig. 4); 2. Grab the peg; 3. Place the peg above the hole; 4. Align the peg and the hole axes; 5. Insert the peg in the hole.



**Figure 4.** The peg and the hole in a virtual environment.

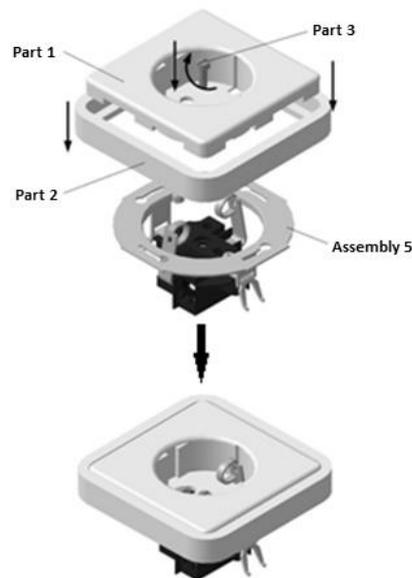
Carrying out tasks in a virtual environment cannot entirely replicate the real process of assembly task (where due to tolerancing and even surface damage, large extraction force or the complete inability to pull out the peg out of the hole may occur), but it may sufficiently well articulate the action of the difficult insertion of the peg into the hole, primarily due to the physics that is an integral part of Unity3D software. In the first experiment, dimensions of the peg were deliberately greater than the dimensions of the hole, so it was impossible to insert the peg in the hole even after multiple attempts of insertion – Fig. 5a). In the second case, dimensions of peg were reduced so that a peg could be placed into the hole – Fig. 5b). There was a slight clearance between components, that made it possible to solve assembly task.



**Figure 5.** a) Impossible insertion, b) clearance between the peg and the hole.

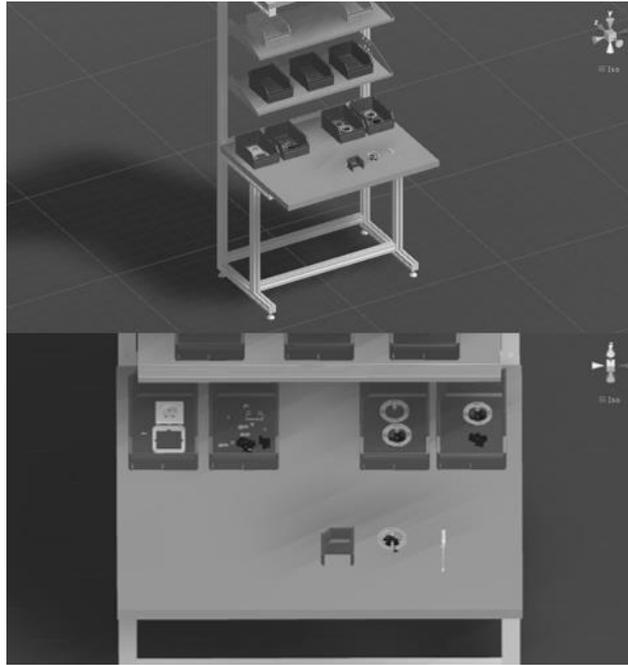
## **WALL SOCKET ASSEMBLY**

Since the use of the wall socket (Fig. 6) is inevitable in every facility where single-phase electric power is used, the wall socket is, therefore, one of the basic electrical installation products with a demand for large production volumes. The virtual task of wall socket assembly will allow a comparison of the time taken to perform assembly actions in the virtual environment, with the time obtained through traditional methods of designing manual assembly task procedures using predetermined motion time system, MTM-2. A wall socket assembly task will be performed for selected components and by appropriate work elements. The work element is the smallest rational part of the work that can be independently run and defines such a state of a partially mounted assembly that it can be moved to another location without unwanted disassembly. The work element is divided into movements which can be described and measured (in VR or by MTM-2).



**Figure 6.** Components of wall socket assembly [18].

The movements of the left and right hand will be dissected on the basic movements, whereby each basic movement will be assigned the standard time towards the type of motion and the condition under which it is performed using normative values of the MTM-2 system. After work analysis and assembly plan have been made, the time taken using traditional process planning using MTM-2 system amounts to 400 TMUs, corresponding to a duration of 14,40 seconds. Subsequently, it is necessary to define the virtual work environment (Fig. 7) in which the assembly task will be executed. It is important that the components for assembly should be properly positioned and oriented, as specified in the assembly plan developed by MTM-2, so it is possible to expect a faithful replication of movements (defined also by MTM-2).



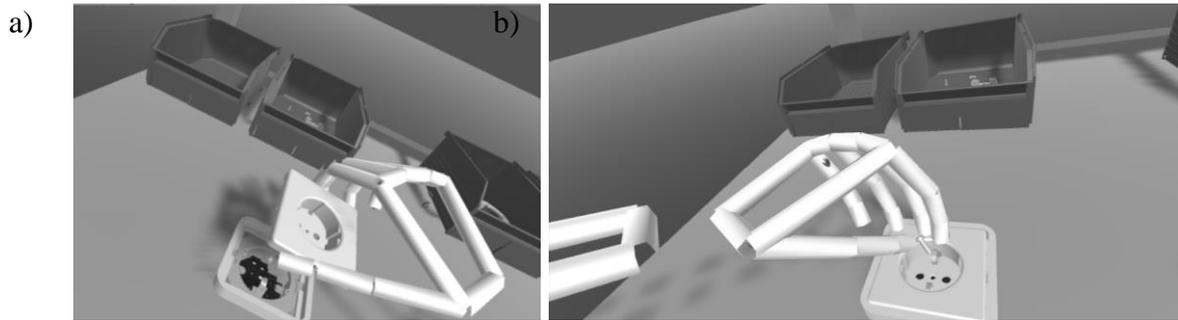
**Figure 7.** Virtual workplace – virtual assembly station with assembly plan features.

Assembly of individual parts will be performed using simple functions which turn on or turn off the graphical representation of individual components at the moment when a collision is detected between parts that need to be assembled.

When the environment is fully defined with so-called *colliders*, scripts and other required software components, wall socket assembly task can be performed (Fig. 8). The execution time of wall socket assembly will be measured with a timer inside the virtual environment. The execution time of wall socket assembly is shown in Table 2.

**Table 2.** Virtual assembly execution time of wall socket assembly.

<b>Assembly action</b>	<b>Duration, s</b>
Getting of Assembly 5 and its positioning	1,83
Getting of Part 1 and Part 2, their mutual positioning and joint positioning in relation to Assembly 5. (Work with both hands)	3,70
Getting of screw and its positioning in relation to Part 1, Part 2 and Assembly 5	3,34
Getting of screwdriver and its positioning on the screw head	2,16
Disposal of screwdriver	0,67
<b>Total duration:</b>	<b>11,70</b>



**Figure 8.** a) Insertion of Part 1 into Part 2, b) Insertion of the screw.

The total duration of the wall socket assembly process in the virtual environment takes 11,70 seconds. For comparison, assembly time of identical process with traditional planning method using MTM-2 technique was estimated at 400 TMUs, which equals a period of 14,40 seconds. Therefore, assembly in a virtual environment has been done for 2,70 seconds less, which means that the process is done roughly 19 % faster than the time scheduled to perform assembly operations through predetermined motion time system.

A shorter time to complete the assembly task in virtual environment may in some way be expected due to the fact that the assembly process, following work analysis, could not be fully replicated due to the lack of virtual environment in terms of the difficult execution of certain actions such as screwing and tightening the screws due to the lack of force feedback. If haptic devices were used, it is expected that the assembly process could be fully replicated, so it may be concluded that virtual assembly and assembly in reality are coincident. Such simple conclusion is of extreme importance for manufacturing and production.

## **ADVANTAGES AND DISADVANTAGES OF USING VR**

Performing the assembly tasks in an immersive environment does not require too long learning, and creates an intuitive environment that can serve to gain experience and simulate work to make it easier to perform in reality. Given the fact that the wall socket is not an assembly that consists of complex geometry, special materials or particularly difficult assembly task for assemblers, the advantage of this approach may not be fully apparent. Virtual training would result in considerably higher savings in complex assembly products, where more advanced assembly operations are required and where potential damage may be caused to highly valuable components if the assembler does not possess certain foreknowledge about the assembly components. Further, in the field of large products (plane and ships), there are great advantages in terms of VR presentation. In a communication between potential owner/investor and manufacturer, VR presentation makes realistic model and is much cheaper than making a physical prototype (1:1), which even may not be possible. VR presents a great advantage in comparison with conventional presentations used in past. Using VR techniques owners/investors can monitor the design and production progress of their order and be important collaborate in early and critical phases where any changes are least expensive.

The advantages and disadvantages of immersive designing of production processes using VR are listed as follows.

Advantages:

- the virtual environment creates an intuitive space where users are easily trained,
- the user in a very short time, within a matter of minutes, can learn how to use the virtual reality device, such as Oculus Rift headset or the Leap Motion Controller,
- there are great savings in design due to easy definition of environment and work tasks,
- excellent visualisation of geometry from any point of view,

- in addition to realistic visualisation, the great advantage of this system is the ability to interact with all types of parts regardless of their size,
- getting acquainted with the product before making a physical prototype,
- once the parts are saved in the appropriate format, one can quickly define the scene for a different geometry,
- it is possible to perform a variety of tasks due to the flexibility of the system,
- assembly can be done at different locations (e.g. at home),
- easy virtual training for different activities,
- the system is suitable for the implementation of ergonomic research (biometrics),
- a virtual environment is a safe environment without the risk of injury to human operators and damage to work parts and tools.

Disadvantages:

- the user may feel slight nausea and discomfort when using the headset device,
- for each particular task, scene should be newly set,
- required conversion of CAD geometry formats into a format suitable for VR development platform,
- limitation of user movements due to geometrical features of the equipment,
- misconfiguring of the user's hands when there is a physical barrier between hand and the Leap Motion Controller sensors, or when device is used in a too bright environment.

## **TEAMWORK AND COLLABORATIVE MAN-MACHINE WORK USING VR**

The VR also presents new views on team work for multiple users involved in a process and collaborative man-machine work, typically simultaneous work of human and robot. Teamwork involving multiple Leap Motion Controllers is a good idea to overcome the limitations that arise when using only the single one. Some restrictions that occur when using Leap Motion Controller are: erroneous detection of user's hands if multiple hands in scene or when obstacles, such as wire (e.g. from a VR headset) exist between the camera, overlapping of user's fingers (e.g. if one hand is below the other, controller will not be able to perceive the lower hand and it will not be detected). The problem that persists when using Leap Motion Controller is well known and is related to the most motion capture systems that use a camera device to capture the user's movements. To overcome mentioned problems, the idea of using multiple Leap Motion Controllers is conceived. That would allow a larger Field-Of-View (FOV) of the device, but also the teamwork of multiple users and their common task execution in the virtual environment. However, using multiple Leap Motion Controllers on a single computer within Unity3D software is not possible at this time without modifications that require the creation of a virtual machine.

Due to built-in physics, Unity3D can also be used in the field of robotics. Initially, the CAD model of robot needs to be imported into Unity3D. Then, it is necessary to define the constraints and relationships between the individual joints of the robot via the embedded joint options. Once the joints are brought into the mutual relationship, it is necessary to approach solving the kinematic problem (e.g. using C# or similar language). When everything is set, the robotic model in the Unity3D can communicate with the real robot via the TCP/IP protocol. The aforementioned principle would be used for direct motion-oriented programming of the robot, where the robot could perform human-induced motion replication from Leap Motion Controller. A particular advantage of human-robot interaction would be visible in some actions of certain production tasks where it is necessary to combine human work (which is sometimes more cost-effective than robots) and robot work. In such situations, the robot would perform tasks where it achieves better results than humans, while humans would execute the tasks that are unprofitable to use robots (e.g. due to complex and changing work environment and high costs). Such work would result in greater flexibility and productivity.

## **CONCLUSIONS AND FURTHER WORK**

Virtual reality has an increasing importance and application in the diverse fields of human activity. The benefits of VR are mostly visible currently in product visualisation and marketing activities, but even larger potential lays in a treatment of VR as a specific tool in integrated and concurrent product, process and system design and planning, including ergonomics and teamwork man-machine research. Also, great potential lies in large and highly competitive industries such as automotive, aerospace and shipbuilding industry where the competition is globally distributed and extremely advanced. The immersive environment provides the ability to join geographically distributed participants in the same discussion within the same environment which is helpful when clarifying essential pieces of information about product characteristics.

The widening availability of equipment and recent commercialisation of VR devices resulted in the easier simulation of processes in production plants such as virtual assembly, without too large investment, at least in the first stage of the research and implementation. Solving tasks in a virtual environment can serve to compare (and re-evaluate) traditional approaches to designing production processes with a modern approach, using VR techniques. Here in the paper, the results of VR assembly planning and classic assembly planning using MTM were compared on wall socket assembly task. Assembly task in a virtual environment was performed faster than the execution time predicted by the MTM-2 system. The difference in time is the consequence of the limitations of the available VR equipment (inability to accomplish all the assignments from work analysis and assembly plan) where the use of the haptic devices would most likely result in overlap of the assembly time in the virtual environment and projected time using the MTM-2 system. This would mean that performing tasks in the virtual environment does not cause additional delays. Reported approach and work done by the authors contribute by the improvements in better connection between CAx and VR software, as well as in immersification of planning of manual work (assembly). Based on the studied literature, the authors did not find that such or similar approach has been implemented so far.

With technology advancement and better quality headsets, the adverse consequences will most likely be reduced to a minimum. A further enhancement is possible using technologies such as 3D scanning that would allow faster incorporation of complex real-world models into CAD software or even directly into VR software, without using formatting tools.

Also, incorporating VR module in CAx software will result with no need to use tedious work of format conversion in the future.

Future work would involve the use of haptic devices for a more faithful replication of the assembly processes and exploration of human-robot interaction (collaborative man-machine work). Obviously, with time span, the area of computer-mediated reality will experience further expansion: this could result not only in a thorough change of the current work and lifestyle of people, but also in unprecedented addressing of problems of the material world and human sensing and reasoning about it.

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# CONTEMPORARY DIGITAL COMPETENCY REVIEW

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## ABSTRACT

According to the European Union's expectations, the Hungarian government set its goal to raise the digital competence level of the population as its importance can no longer be questioned. The opportunity to increase the users' level of digital competency, and the examination of the results achieved will make the training more effective. Digital knowledge must be increased so as to make digital goods equally accessible to everyone. Most of the workplaces and professions require a certain level of digital literacy, that is both employees and the companies need to know what level of digital skills are and will be required across the workforce.

## KEYWORDS

digital competency, digital literacy, digital skills, safety awareness, industry 4.0

## CLASSIFICATION

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## **INTRODUCTION**

The Hungarian government, as every other developed country government realized the important problem which was generated in the last twenty years and accelerated, which is none other than the lack of digital competency in the Hungarian population. The Internet as a developing infrastructure causes economic operators also put more emphasis on digital development. In the last twenty years a lot of new industries were developed, which are specifically built on digitalization [1]. Let us think here about net stores, services built on determining digital geolocation, or even the whole online world. The possibilities given by ICT are more and more popular, even the “traditional” industry has gone through a huge digitalization revolution. So as we can see today’s employee and the upgrowing generation need a new skill and that is digital competency [2].

## **DIGITAL WEALTH**

It is a fundamental expectation of the members of an information or knowledge-based society that such a society should ensure them wealth. In this case, wealth means digital wealth, such as electronic commerce, banking, education or administration. However, it is the fundamental expectation of the society that its individual members access, use and prosper from digital wealth in order to improve their lives. Of course, all this should be achieved in a way that is safe for everyone. The individual is just as responsible for gaining access to the wealth ensured to them as the leadership of the society. Therefore, it cannot be said that the only responsibility of the State is to increase the digital capacity of the public. All efforts of the Government are in vain, if the individuals fail to do anything to achieve these goals, and to meet the aspirations of both the individual and the Government [3].

## **DIGITAL PROSPERITY**

It is the individual’s best interest to learn how to use those utilities which serve their welfare. Due to industrialization in the 20th century, people gained access to tramway networks, piped drinking water, sewerage, gas and landline telephone networks. These utilities have greatly improved social comfort. And then, at the end of the 20th century, the Internet appeared, as the largest public information network. Over the last half century the explosion of information technology development has resulted in the spread of information systems. A growing number of people have encountered computer systems in their everyday lives [4].

## **RETROSPECTION**

Some of them first met with information technology applications at work or during their studies in the 1980’s, which later had a further effect on their lives [5]. Some people only heard about the existence of such applications, but their lives were not affected directly by them. And then, in the 1990’s, computers appeared in more and more workplaces, which meant that an increased number of people had direct contact with computer systems [6]. The scope of education has also widened in this field. The previously mentioned emergence of the World Wide Web helped the spread of the Internet [7]. Then the first smart phones became available at the beginning and in the middle of the 2000’s, capable of internet access. Of course, this required the tremendous development of mobile phone service providers and cable TV operators [1]. IT solutions became available in all areas of life, changing them completely. It has developed to such extent, that if IT systems fail to work for some reasons (power supply problem, hardware/software problem, transmission path problem, or deliberate injury), it could stop the normal course of life. The fact that IT is present everywhere means that our lives have become easier. We are able to make arrangements, do the shopping or banking, keep in touch with family and friends in a faster, cheaper and easier way by using the Internet.

## **GENERATION GAP**

As technology evolved, the different generations had to change and adapt as well. Today, the members of generations Y and Z are now called “digital natives”. The presence of information technology is completely natural for them, as electricity and piped water for the members of generation X. Information technology, however, should not only make the lives of generations Y and Z easier, but also the lives of all generations, similarly to all the other utilities which make life more comfortable and of which all generations can take advantage. It is false to assume that now all children understand computers and cell phones. It is true at a certain level, but in most cases, they have no idea about security, and this can cause serious problems. Information technology or digital literacy is not an innate ability, but a skill that one must learn or acquire, since no one is born with the ability of using a spreadsheet or a word processing program. Yet, the misconception about digital natives still persists.

## **THE DIGITAL SKILLS OF YOUNG PEOPLE**

According to a survey carried out by the British Computer Society, only 52 % of the employers think that their employees have the appropriate digital skills. Research made in Germany and Austria shows that while many people consider themselves digitally literate, the tests revealed that many of them were unable to perform even the most basic operations. It should be made clear that being able to use a Smartphone or to chat with friends on a social networking site is by no means the same as being digitally literate. It is a further problem that the concept of “digital literacy” is not defined; practically it can mean anything. A survey conducted by the Italian University, 42 % of university students are not aware of the dangers of free Wi-Fi, 40 % of them do not protect their phones by a pin-code, and 50 % of them download anything to their computers without checking the source. The International Computer and Information Literacy Study (ICILS) conducted a survey among 60 000 young people, which showed that 17 % of those participating in the survey failed to meet even the most basic requirements, and only 2 % had a high level of knowledge necessary for conscious facility sharing [8].

## **WHAT IS DIGITAL COMPETENCY?**

The skill that the public, businesses and public administration’s digital competence development can be done by increasing digital literacy and the digital division mitigation can be implemented so that it enables the users to identify and utilize for standing by the introduction of information and communication systems business opportunities, as well as the long-term falling behind in the digital ecosystem benefits of preference, that is e-inclusion [9].

## **ONE OF THE DEFINITIONS OF DIGITAL COMPETENCE**

Antonio Calvani and collaborators defined the digital competence as “to explore and face new technological situations in a flexible way, to analyze, select and critically evaluate data and information, to exploit technological potentials in order to represent and solve problems and build shared and collaborative knowledge, while fostering awareness of one’s own personal responsibilities and the respect of reciprocal rights/obligations.” (Fig.1). This definition emphasizes the co-existence of three dimensions and their integration: 1) technological dimension; being able to explore and face problems and new, 2) technological contexts in a flexible way, and 3) cognitive dimension; being able to read, select, interpret and evaluate data and information taking into account their pertinence and reliability; ethical dimension: being able to interact with other individuals constructively and with a sense of responsibility towards oneself and towards others [10].

## Abilities and skills

In addition to that digital competence, and the use of digital media confidently and critically at work, during leisure time and communication too. This ability of logical and critical thinking is connected to a high level of advanced information management and communication skills. The skills related to the use of ICT technology (ICT) in the most basic level of digital content, includes information search, evaluation, storage, creation, presentation and transmission, as well as online communication and social networking with the ability of participation [12].

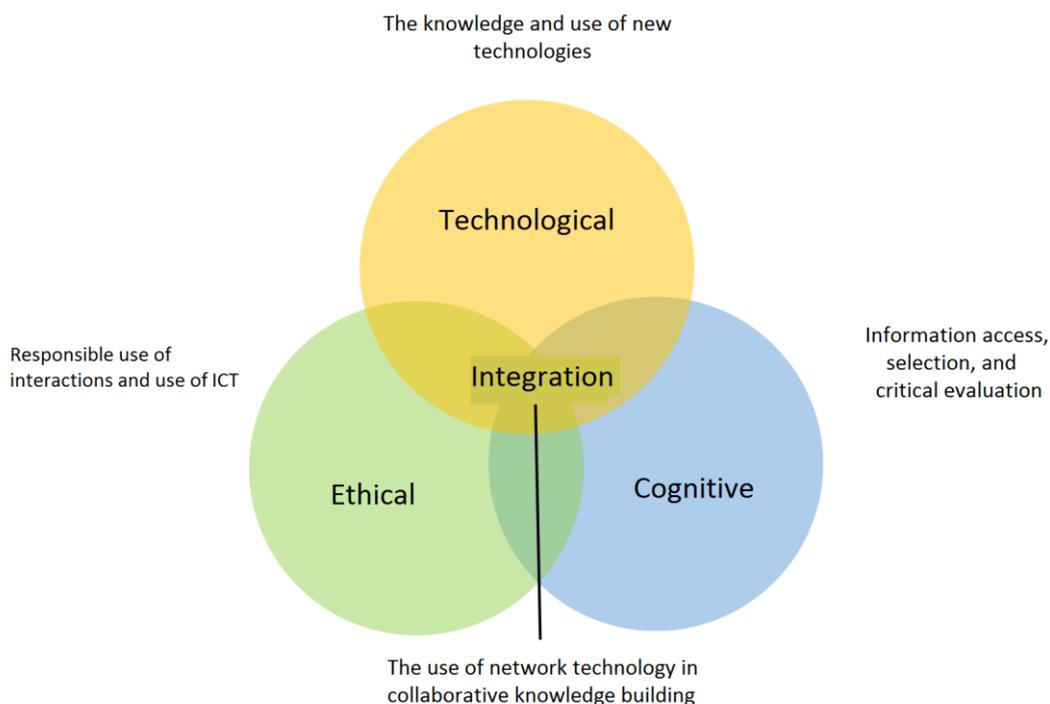


Figure 1. Dimensions of digital competency [10].

## DIGITAL LITERACY

Digital literacy covers a several types of literacy, functional literacy is aligned under writing, reading, and counting. It includes comprehensive reading and the critical use of the information obtained. The aspects of this kind of literacy is the use of libraries, application skills of search strategies, the evaluation and its critical handling skills – including the mass media conveyed information – handling, that is the media literacy [12].

## THE IMPORTANCE OF DIGITAL COMPETENCE

There is an increasing need for professionals capable of managing the used digital tools. The modern professional skills require knowledge of digital tools even for the already existing so called “traditional” professions, too. Then the employee can work effectively, if the handling of the machine does not present a challenge. The emergence of the above-mentioned digitization is a real challenge of contemporary 35 years and older age group among employees. The formerly learned already lapsed. The company does not train their own employees or does so in small numbers.

## **THE ECONOMIC IMPACT**

The digital competence impact on GDP is remarkable, because digital literacy increase with 1 % leads to the increase of GDP to 0,123 %, which causes a surplus of 34,7 billion GDP. The ICT sector created info-communications and IT industry accounts for about 12 % of the Hungarian GDP, and the number of employed in the sector compared with most OECD countries is extremely high in our country [13].

## **SURVEYS RELATED TO DIGITAL COMPETENCE AND SECURITY**

Further in the text I will present surveys. These surveys were conducted among Hungarian young people. The topics of the surveys are digital competence and security awareness. Surveys were made by various organizations. Surveys have been made recently (Fig. 2).

### **UNICEF HUNGARIAN COMMITTEE SURVEY**

A non-representative survey conducted in the autumn of 2014 by the Hungarian Committee of UNICEFF gave the following results in which 1191 people, 10-19 years elementary and high school students were involved. 96 % of those surveyed own a mobile phone and 88% have profile on a social networking site. According to the survey, 50 % of children do not consider the Internet to be safe. 33 % of children have been a target of “harassment” on the Internet. In such cases, half the victim children of the harassment tried to defend their self, but only 10 % sought help [13].

### **THE EU KIDS ONLINE INTERNATIONAL SURVEY**

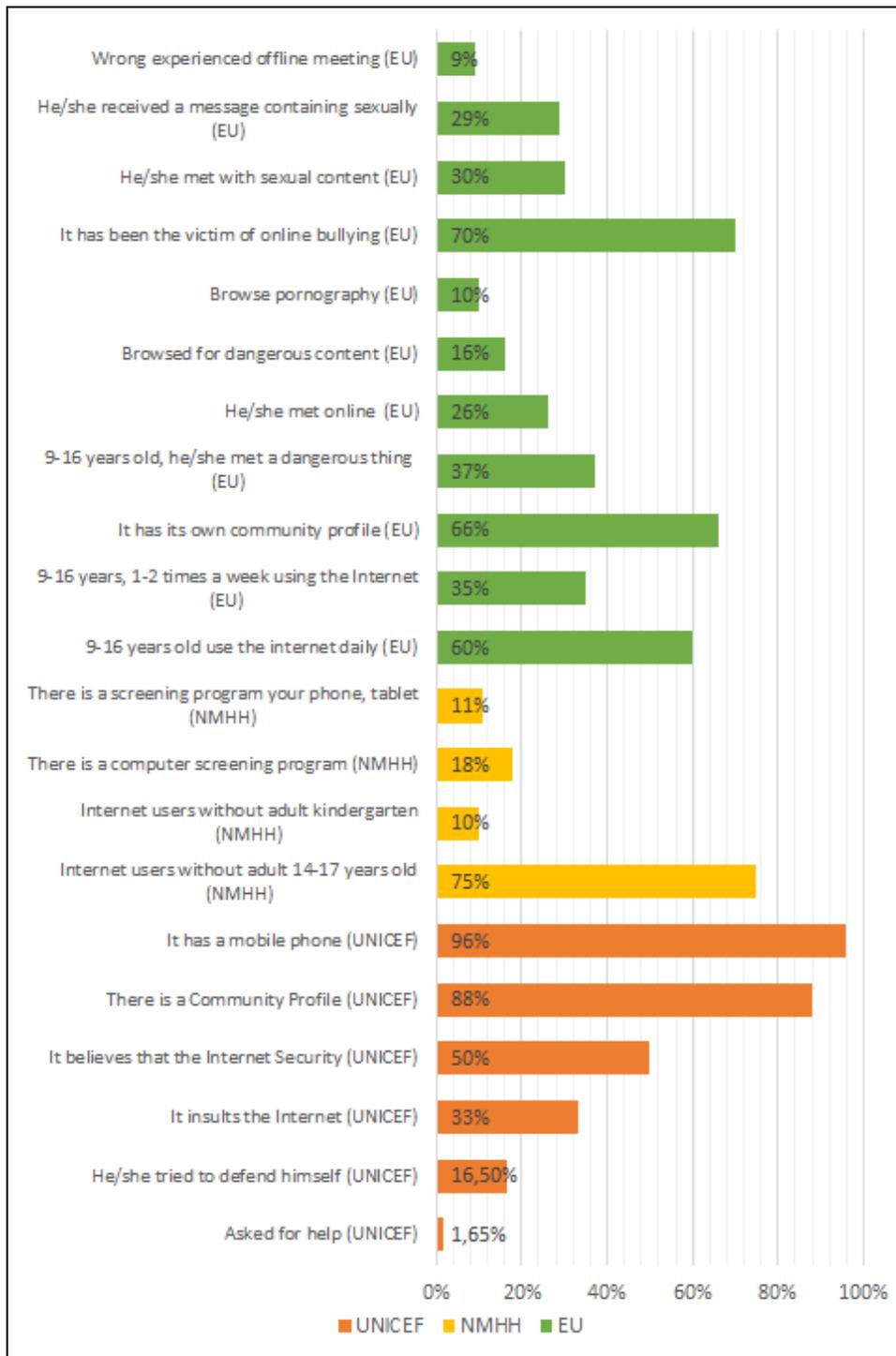
With the support of the European Commission’s Safer Internet Program, EU Kids Online their international series of studies conducted in 25 countries. According to the survey, the average Hungarian children begin to use the internet independently at the age of 9. Forecast predicts that this age will be reduced, most probably will stabilize at around 5-6 years of age. The 9-16 age group’s 60 % uses the Internet on a daily basis, in contrast around 35 % are those children who use the internet a couple of times a week. Two thirds of this age group have their own profile on social networking sites. 37 % of the Hungarian 9-16 year olds encountered at least one hazardous activity on the online space. 26 % of the children have already got acquainted with others online. 16 % of the children has browsed dangerous content. Everyone in ten children have experience in browsing pornographic content. Nearly 70 % of the children interviewed had already the victim of online bullying. 30 % of the children met with sexual content, and 29 % of children were affected by sexual messages and actions. 9 % of the children was part of an “offline” meeting ending in a bad experience, which was preceded by online acquaintance [13].

### **THE NMHH SURVEY**

The NMHH is a Hungarian acronym word means National Media and Infocommunications Authority. Three-quarters of the children between the age of 14 and 17 usually uses the internet without adults present. According to a survey conducted by the NMHH in 2013: 10 % of the Internet users living in the same household as pre-schoolers said that, the children under 6 living with them, use phone or tablet to use the internet without the help of adults. A small portion of those surveyed answered that his or her parents installed a screening program on the computer (18 %), or phone and tablet (11 %) which the child uses [14].

## **CONCLUSION**

It is clear from the aforementioned that parents, educators and teachers awareness is a crucial aspect of this area. As long those taking part in the education of the children do not have the adequate digital knowledge as well as the intention and ability to pass them on, then it has



**Figure 2.** The diagram of the results of the different surveys.

serious consequences. Unfortunately, a very small proportion of the teachers possesses the necessary skills [14]. Many non-governmental organizations engaged in training, not only for kids but has also aimed to expand the knowledge of pedagogues. A misconception in relation to the older retired generation that above a certain age the necessary digital competence already cannot be acquired. The Lifelong Learning in Western European societies is a successful state-sponsored initiative and process where the positive impact is not only measurable on those concerned [15-19].

The importance of adults' digital competence, based on what is stated previously is not questionable. The government's praiseworthy strategies aims to increase children's digital

competence and within that digital literacy [20]. Unfortunately, they do not extend to the development of the population's general purpose digital competence and digital literacy [21]. If the companies and businesses would receive state-supported educational opportunities for increasing the general digital competence of the staff, then in that case the general digital culture of the Hungarian population would start a huge growth that would serve the nation's economic growth [22-24].

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# COMPENSATION OF DIGITAL COMPETENCE DEFICIENCY WITH SOFTWARE ERGONOMIC TOOLS

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## ABSTRACT

In the contemporary digital world, a lot of information needs to be processed every day. Our security depends on the quick and accurate processing of this information. Figure-based information processing is faster and simpler than the text-based one. The level of IT skills and skills may be lower in this way, so a system that is applicable to a broader social circle is needed. The solution would be to make the use of info-communication tools accessible to people with low vision, those with learning difficulties, non-speakers, the elderly and children who are unable to read because of their age. In this article, the author attempts to illustrate the difference in the processing of visual and textual information through a simple survey and make recommendations for the ergonomic compensation of digital competence gaps with software.

## KEYWORDS

safety awareness, digital competency, software ergonomics

## CLASSIFICATION

JEL: O10, Q55

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## **INFORMATION FLOW AND PROCESSING SPEED**

The modern-day information transmission speed and rate in the last 100-150 years has significantly accelerated compared to the previous period [1]. In the previous period, mass media and information reached only a very narrow circle or significantly distorted information before it reached the people [2].

## **INFORMATION HUNGER OF A KNOWLEDGE-BASED SOCIETY**

Here the focus is not on industrial societies, but on the knowledge-based, information societies. The principles of computer, historically put down by John von Neumann along with the creation of electronic computers (EDVAC, 1949), greatly contributed to modern spread of the informatics and information technology throughout our lives [3].

## **THE PROBLEM OF INFORMATION PROCESSING AS A SECURITY CHALLENGE**

We have access to information in the visual and audio-visual form of the IT interface. We have the information in the form of text, images, audio and video [4].

Electronic devices that display information “communicate” with us. In other words, they expect a different decision in the form of messages to inform the user. The user’s decision is executed in a predefined manner. These are usually called pop-up windows [5]. In order for the user to take his decision and issue the command given in the message, he or she needs to be informed [6]. The initial data is usually found in the pop-up window. This information is usually available in text format [7]. In a good case scenario, the text message will inform the user in the user’s native language, but in other case in a foreign language [8]. It may also happen that although the user receives the information in his or her mother tongue, the user may not understand the terminology if he or she is not familiar with that level of knowledge or because that their general literacy skills are low or illiterate (e.g., preschool-age children) [9]. But they may also have reading difficulties, which is a common phenomenon at the present. It is also possible that in the absence of visual acuity (glasses, contact lenses), they cannot read the message [10]. In this case, the user cannot access or understand information contained in the data provided. This is a critical level security problem [11]. That problem is comparable to the problem of driving without understanding of the driving signs and traffic lights [12].

## **SOFTWARE ERGONOMIC SOLUTION OF THE INFORMATION PROCESSING PROBLEM**

Software ergonomics standard ISO 9241 gives developers a point of reference in order to create an ergonomic system. The ISO 9241 standard is intended to promote the ergonomic design of a screen work and to ensure that screen operators can reliably, efficiently and effectively manage screen operations. ISO 9241 addresses the requirements and guidelines for the hardware, the software and the environment features that contribute to the usability and the ergonomic principles underlying them [13].

Stated security issues are challenges that need to be considered urgently. The internet is nowadays available to many people, since many of them have mobile or other devices that have access to the internet in some form [14].

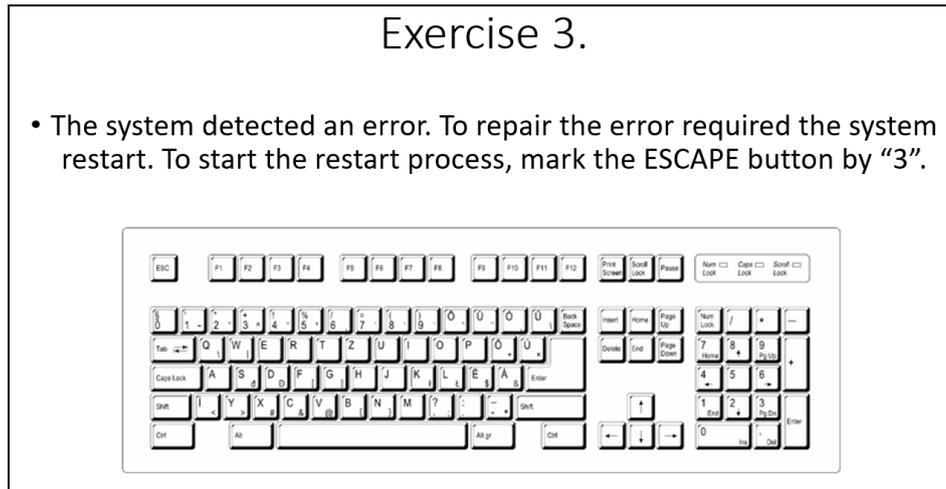
## **TEXT MESSAGE VERSUS PICTOGRAM MESSAGE**

However, for the users faced with the aforementioned problem, the vulnerability as a result of the improper handling of text pop-up messages, we should find some form of secure solution.

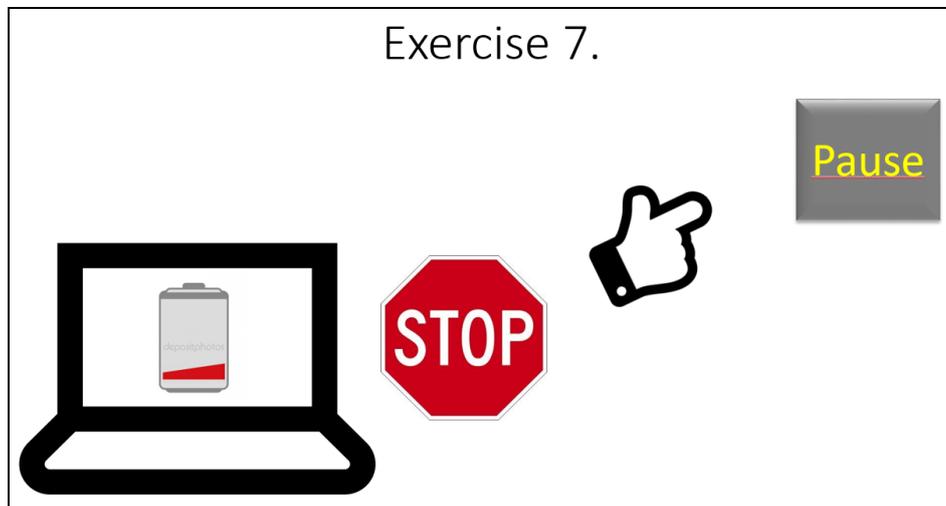
## DEVELOPMENT OF THE TEST TASKS

The hypothesis is that, in contrast to pop-up text messages, the interpretation of pictogram messages is simpler in the case of a short reaction time. The hypothesis will be tested by conducting a research. The corresponding experiment consists of two phases.

I prepared a set of sample tasks that contain fictitious pop-up messages in a single text form (Figure 1), as well as the pictograms version (Figure 2). The task sequences were reserved for a single MS PowerPoint slideshow. The slideshows contain 10 tasks as described previously, with the difference that the tasks do not follow each other in the two slideshows. Each of the slides contains one task to be executed. The slides changed automatically every 5 seconds.



**Figure 1.** One of the tasks of the text test.



**Figure 2.** One of the tasks of the pictogram test.

## CONCEPTUALISING THE TEST TASKS

I prepared a paper-based worksheet for the task series, with a description of the task execution and a drawing of a computer keyboard (Figure 3).

In three out of the ten tasks, there is more than one option. For each task, a different key was assigned to the task executor in order to avoid the fact that the exact answer cannot be determined in evaluation. In the case of pictorial slideshow, if the attention or danger was presented, I used the pictures representing the road signs.

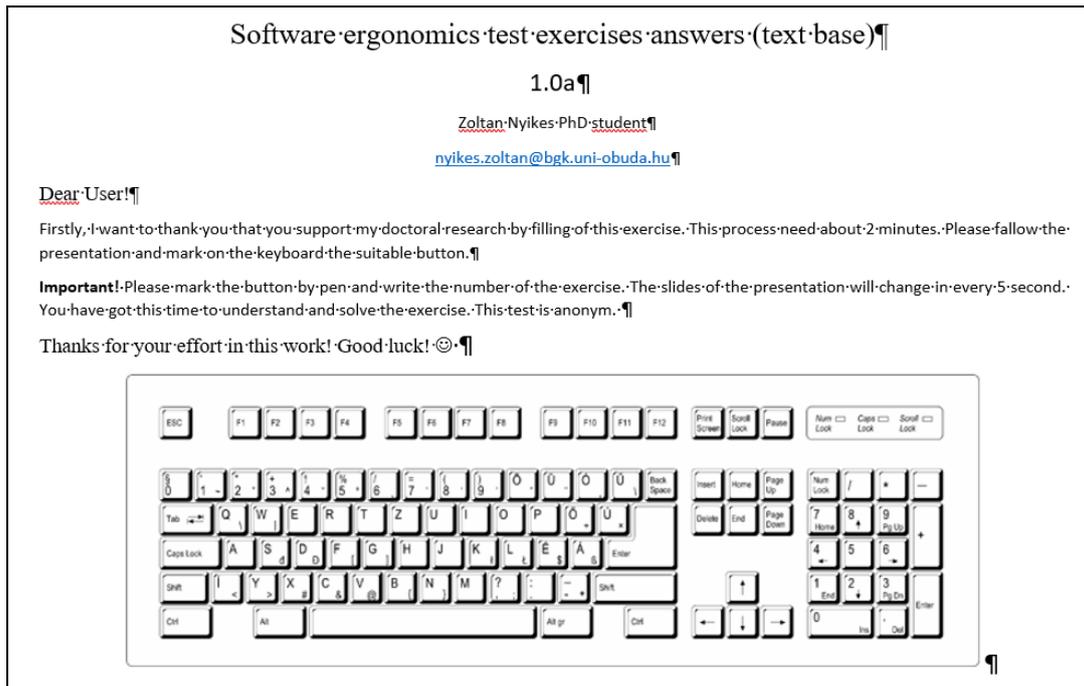


Figure 3. One of the tasks in the paper-based worksheet prepared for the test.

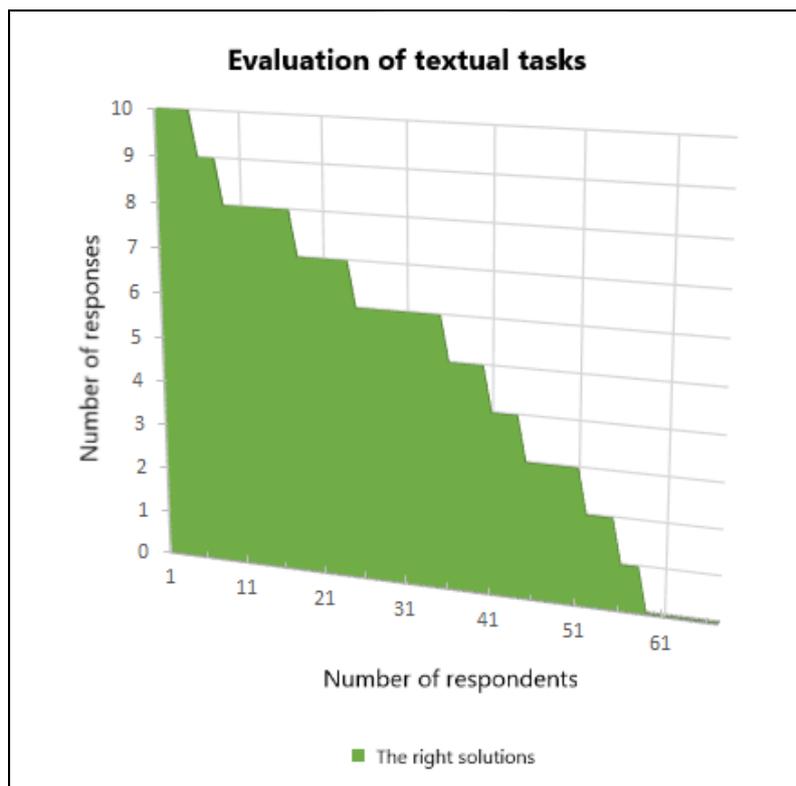
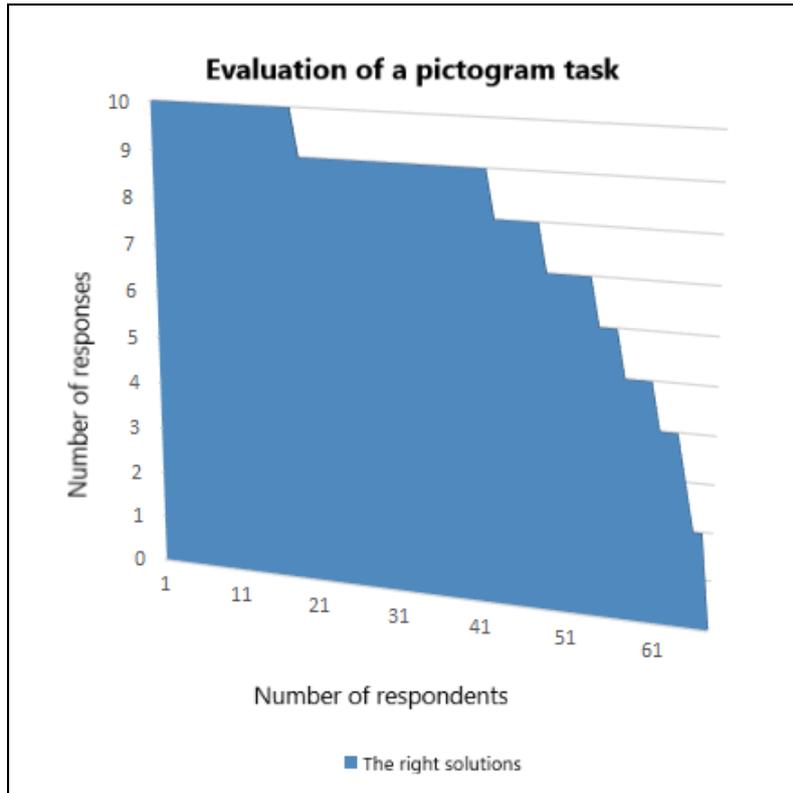


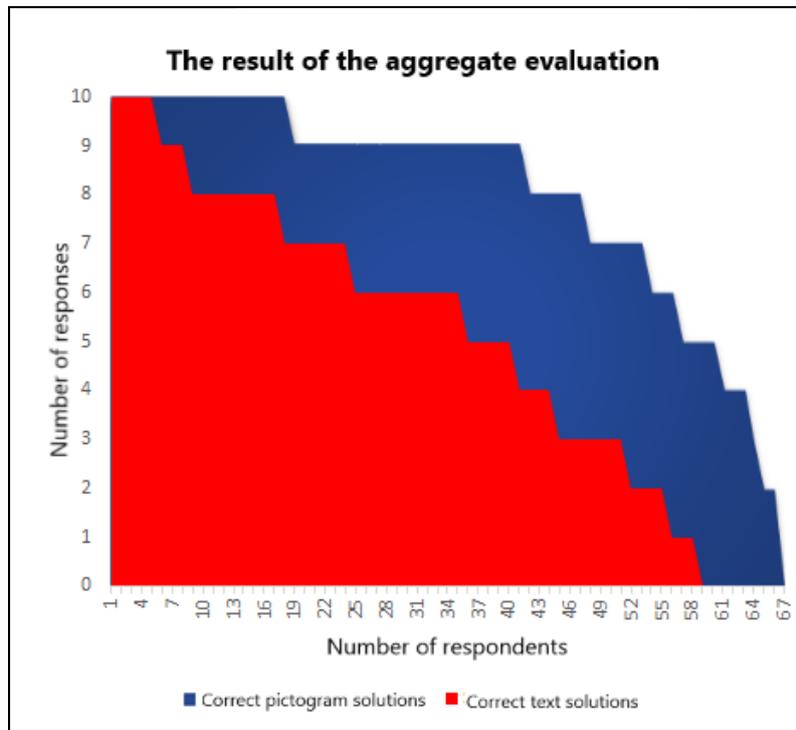
Figure 4. Diagram of evaluation of the text task.

## PERFORMING THE TEST TASKS

The preliminary experiment was carried out with 67 full-time and correspondent MSc and BSc student group. First, they had to execute the text queue and then the pictograms on a separate task sheet. 10 questions could be answered by 10 good answers. If there were more than one key in a task, but only one or only one combination of keys needed for the task, and the respondent had more than one option, I evaluated it as a mistake.



**Figure 5.** Diagram of evaluation of the pictogram task.



**Figure 6.** The cumulative evaluation diagram.

### EVALUATION OF THE RESULTS OBTAINED

In the case of the textual task (Figure 4), results of a minimum of 50 % and above were achieved by a total of 40 respondents, accounting for nearly 60 % of respondents. There were 9 respondents (about 13 % of respondents) who, for some reason, did not give any answer.

In the case of pictograms (Figure 5), a 50 % or more was achieved by 60 respondents, accounting for 89 % of respondents. Of the responses in this task type, one did not have any answers. It can be seen that there were 10 respondents who did not make a bad answer, accounting for nearly 15 % of respondents. From the cumulative results (Figure 6) of the textual and pictogram tasks, the results of the pictogram tasks were far better. Tasks could be performed in the same unit amount of time. This means that the text task was not understood as quickly as the pictograms.

## CONCLUSIONS

This article developed a solution proposal that would be a safe, a short- and a mid-term approach to solving the user's security challenges in information processing and user response using software ergonomic. I took into account the current software ergonomic rules in developing pictogram test messages instead of the text messages. The evaluation of the test tasks shows that a significant proportion of users had a good solution of at least 50 % for pictograms, which was about 30 % more than the executives of the textual task. This difference contributes to proving the correctness of the stated hypothesis.

In my further research, I would like to propose the development of an online Emergency Aid Help Line, where the user can detect an attack on the Internet by using the help of a 7/24 Emergency Center in order to protect his/her infocommunication tools.

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# DEVELOPMENT OF THE AUTONOMOUS ANTHROPOMORPHIC WHEELED MOBILE ROBOTIC PLATFORM

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## ABSTRACT

This article presents the intelligent autonomous anthropomorphic wheeled mobile robotic platform motion control in unstructured environments. The fuzzy control of a wheeled autonomous anthropomorphic mobile robotic platform motion in unstructured environments with obstacles is proposed. Outputs of the fuzzy controller are the angular speed difference between the left and right wheels of the autonomous anthropomorphic robotic platform and the robot velocity. The simulation results show the effectiveness and the validity of the obstacle avoidance behaviour in the unstructured environment and velocity control of autonomous anthropomorphic mobile robotic platform motion of the proposed fuzzy control strategy. Wireless sensor-based remote control of autonomous anthropomorphic mobile robotic platform motion in unstructured environments is proposed.

## KEYWORDS

autonomous anthropomorphic wheeled mobile robotic platform, unstructured environments with obstacles, fuzzy control strategy, wireless sensor-based remote control

## CLASSIFICATION

ACM: D.1.1.

JEL: Z00

## INTRODUCTION

Currently, research in robotics, deals with different problems of motion of wheeled mobile robots and the motion control of wheeled mobile robots in unstructured environments. Autonomous navigation is an important problem in mobile robotics. Fuzzy logic approaches to mobile robot navigation and obstacle avoidance have been investigated by several researchers. Many application works of fuzzy logic in the mobile robot field have given promising results.

In recent years, there has been a growing interest in autonomous anthropomorphic mobile robotic platform motion control [1, 2]. This article presents autonomous anthropomorphic wheeled mobile robotic platform motion control in unstructured environments.

The article deals with the fuzzy velocity control of an autonomous anthropomorphic mobile robotic platform in motion in an unstructured environment with obstacles. For the wireless, sensor-based remote control the Sun-SPOT-based remote control is utilised. Conventionally, autonomous anthropomorphic mobile robotic platforms are equipped by ultrasonic sensors and a stereo-vision system. The wheeled mobile robot must be capable of sensing its environment. It is supposed that the autonomous anthropomorphic mobile robotic platform has groups of ultrasonic sensors to detect obstacles in the front, to the right and to the left of the platform, that the model of the autonomous anthropomorphic mobile robotic platform has two driving wheels and that the angular velocities of the two wheels are independently controlled. When the anthropomorphic mobile robotic platform [1, 2], is moving towards the target and the sensors detect an obstacle or slope an avoiding strategy is necessary (Fig. 1). While the anthropomorphic mobile robotic platform is moving it is important to compromise between avoiding the obstacles, slopes and moving towards the target position.

The fuzzy control of a wheeled anthropomorphic mobile robotic platform motion in unstructured environments with obstacles and slopes is proposed. Outputs of the fuzzy controller are the angular speed difference between the left and right wheels of the platform and the platform velocity.



**Figure 1.** The autonomous anthropomorphic mobile robotic platform.

The simulation results show the effectiveness and the validity of the obstacle avoidance behavior in unstructured environment and velocity control of a wheeled mobile robot platform motion of the proposed fuzzy control strategy. The wireless sensor-based remote control of anthropomorphic mobile robotic platforms motion in unstructured environments using the Sun SPOT technology is proposed. The proposed method has been implemented on the wheeled anthropomorphic mobile robotic platform that is equipped with sensors and the free range Spot from the Sun Spot technology. Finally, the effectiveness and efficiency of the proposed sensor-based remote control strategy are demonstrated by experimental studies and good experimental results of the obstacle avoidance behavior in unstructured environments.

The article is organized as follows. In Section 1 introduction to the topic is given. In Section 2 the strategy of autonomous anthropomorphic mobile robotic platform control in unstructured environments is proposed. Section 3 illustrates the simulation results, while in Section 4 the wireless robot-sensor networked systems are illustrated and the Sun-SPOT-based remote control of autonomous anthropomorphic mobile robotic platform is proposed. Finally, in Section 5 conclusions are given.

## **STRATEGY OF AUTONOMOUS ANTHROPOMORPHIC WHEELED MOBILE ROBOTIC PLATFORM MOTION CONTROL IN UNSTRUCTURED ENVIRONMENTS**

In this section fuzzy control is applied to the navigation of the autonomous anthropomorphic mobile robotic platform in unstructured environments with obstacles and slopes. It is supposed that: the autonomous mobile robotic platform has two wheels driven independently and groups of ultrasonic sensors to detect obstacles in the front, to the right and to the left of the autonomous mobile robotic platform.

When the autonomous mobile robotic platform is moving towards the target and the sensors detect an obstacle, an avoiding strategy is necessary [3-13]. While the autonomous mobile robotic platform is moving it is important to compromise between [13]:

- avoiding the obstacles and
- moving towards the target position.

With obstacles present in the unknown environment, the autonomous mobile robotic platform reacts based on both the sensed information of the obstacles and the relative position of the target [13]. In moving towards the target and avoiding obstacles, the autonomous mobile robotic platform changes its [13]:

- orientation and
- velocity.

When an obstacle in an unknown environment is very close, the mobile robot slows down and rapidly changes its orientation [13]. The navigation strategy has to come as near as possible to the target position while avoiding collision with the obstacles in an unknown environment [13].

The intelligent autonomous mobile robotic platform reactive behaviour is formulated in fuzzy rules [14-25]. Fuzzy-logic-based control is applied to realize an autonomous mobile robotic platform in an unknown environment with obstacles.

Inputs to the fuzzy controller are:

- the obstacle distance  $p$ ,
- the obstacle orientation  $\theta_1$  (which is the angle between the mobile robotic platform moving direction and the line connecting the robot's centre with the obstacle),
- the target distance  $l$ ,

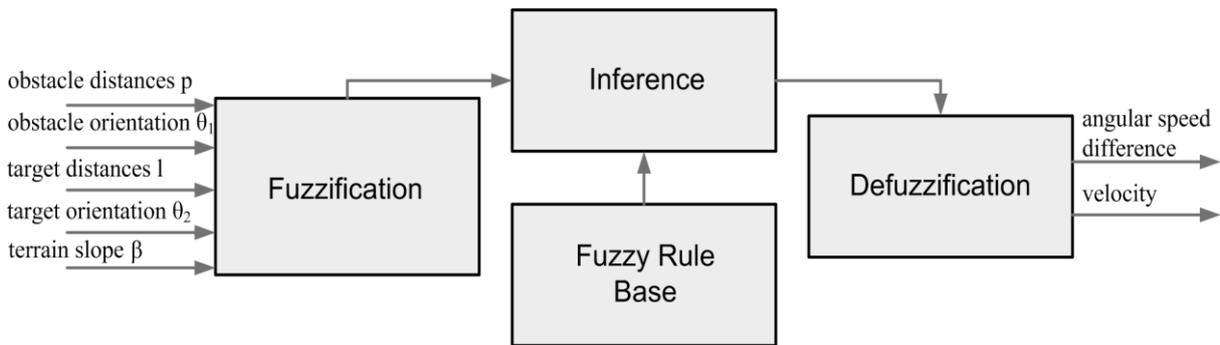
- the target orientation  $\theta_2$  (which is the angle between the robot platform moving direction and the line connecting the platform's centre with the target).

Outputs of the fuzzy controller are:

- the angular speed difference between the left and right wheels (wheel angular speed correction) of the vehicle:  $\Delta\omega = \omega_r - \omega_l$  and
- the vehicle velocity.

The block diagram of the fuzzy inference system is presented in Figure 2.

The obstacle orientation  $\theta_1$  and the target orientation  $\theta_2$  are determined by the obstacle/target position and the robot position in a world coordinate system, respectively. The obstacle orientation  $\theta_1$  and the target orientation  $\theta_2$  are defined as positive when the obstacle/target is located to the right of the platforms direction of movement; otherwise, the obstacle orientation  $\theta_1$  and the target orientation  $\theta_2$  are negative.



**Figure 2.** The block diagram of the fuzzy inference system [13].

For the proposed fuzzy controller the input variables for the obstacle distance  $p$  are simply expressed using two linguistic labels – Gaussian membership functions – near and far ( $p \in [0, 3 \text{ m}]$ ).

The input variables for the obstacle orientation  $\theta_1$  are expressed using two linguistic labels – Gaussian membership functions – left and right ( $\theta_1 \in [-\pi, \pi \text{ rad}]$ ).

For the proposed fuzzy controller the input variables for the terrain slope  $\beta$  is simply expressed using three linguistic labels – Gaussian membership functions sloped left, flat and sloped right ( $\beta \in [-\pi, \pi \text{ rad}]$ ),  $\beta$  is the average slope value.

The input variables for the target distance  $l$  are simply expressed using two linguistic labels – Gaussian membership functions – near and far ( $l \in [0, 3 \text{ m}]$ ).

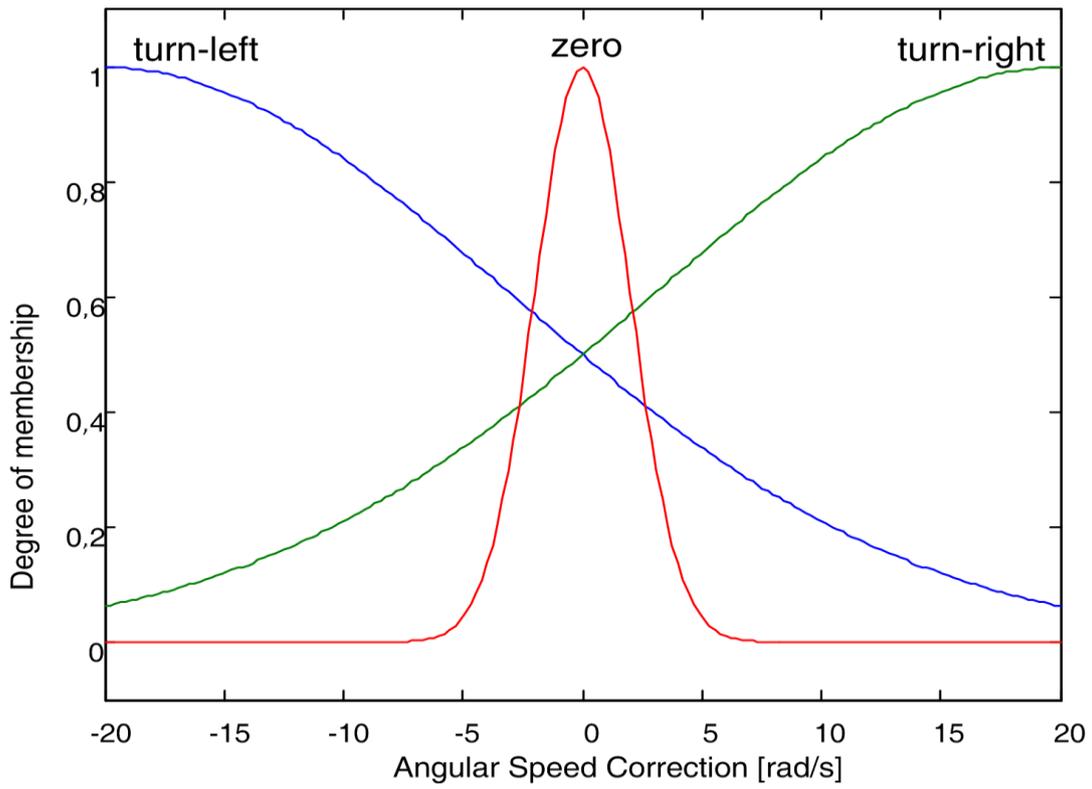
The input variables for the target orientation  $\theta_2$  are simply expressed using three linguistic labels – Gaussian membership functions – left, target direction and right ( $\theta_2 \in [-\pi, \pi \text{ rad}]$ ).

The fuzzy sets for the output variables of the wheel angular speed correction  $\Delta\omega = \omega_r - \omega_l$  (turn-right, zero and turn-left) of the mobile robot are shown in Figure 3. The output variables are normalized in the interval:  $\Delta\omega, \text{ rad/s} \in [-20, 20]$ .

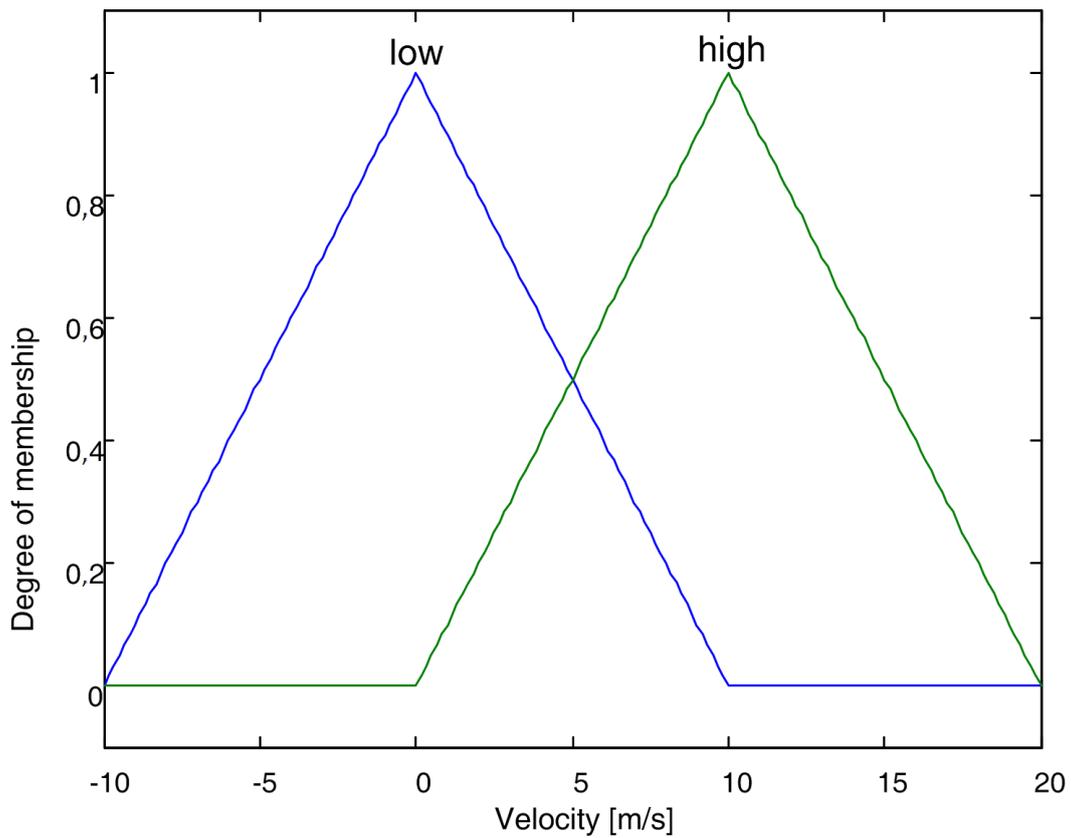
The other output variable of the fuzzy controller is vehicle velocity. The output variables are normalized between: Velocity,  $\text{m/s} \in [-10, 20]$ . The fuzzy sets for the output variables Velocity (low and high) are shown in Figure 4.

The rule-base for mobile robot fuzzy control is:

- R1: If  $\theta_2$  is right and  $\beta$  is sloped left then  $\Delta\omega$  is turn-right
- R2: If  $\theta_2$  is left and  $\beta$  is sloped right then  $\Delta\omega$  is turn-left
- R3: If  $p$  is near and  $l$  is far and  $\theta_1$  is left and  $\beta$  is sloped left then  $\Delta\omega$  is turn-right



**Figure 3.** The Membership functions of the angular speed difference  $\Delta\omega$ .



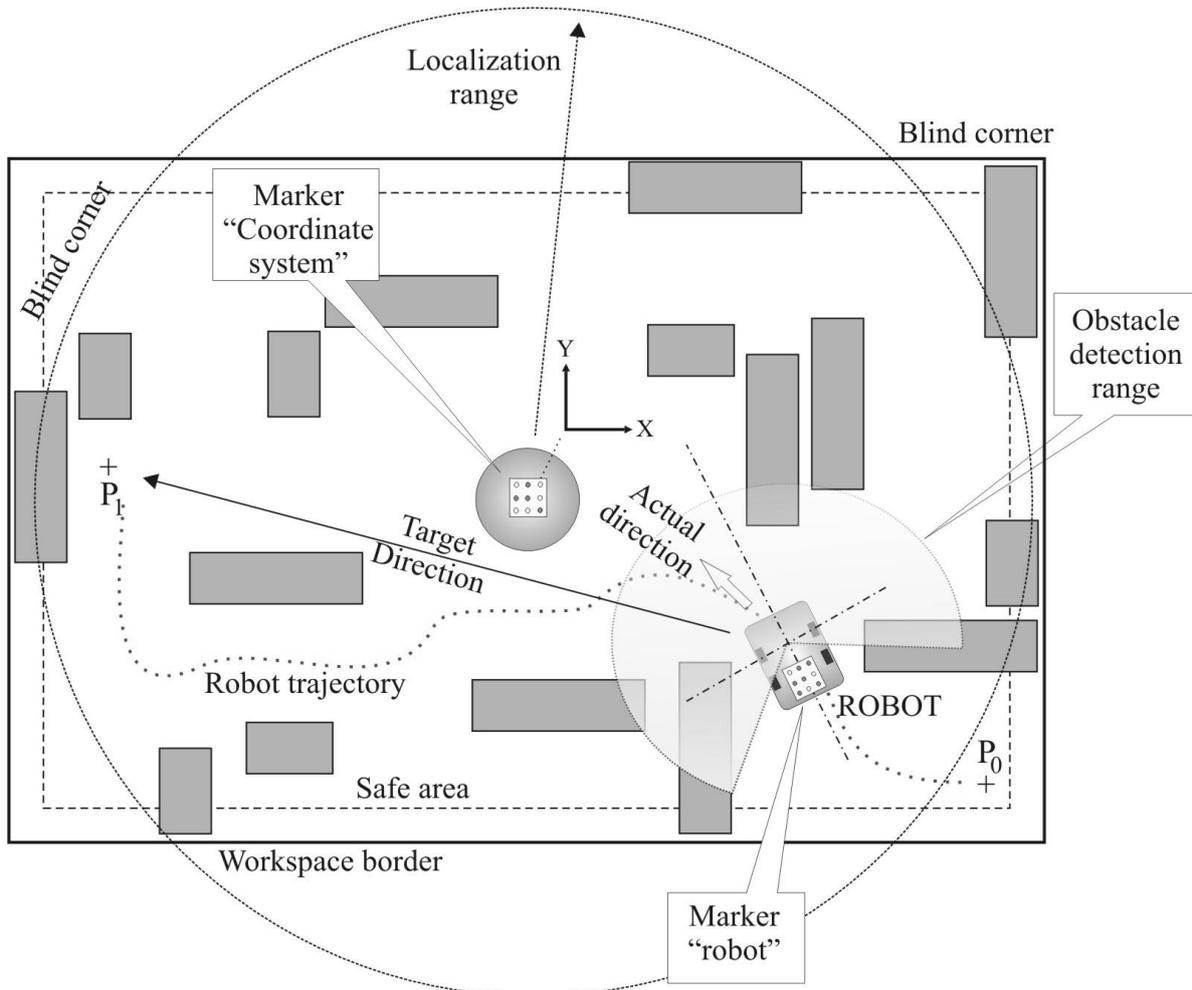
**Figure 4.** The Membership functions of the velocity of the mobile robot platform.

- R4: If  $p$  is near and  $l$  is far and  $\theta_1$  is right and  $\beta$  is sloped right then  $\Delta\omega$  is turn-left  
 R5: If  $\theta_2$  is target direction and  $\beta$  is flat then  $\Delta\omega$  is zero  
 R6: If  $p$  is far and  $\theta_2$  is target direction and  $\beta$  is flat then  $\Delta\omega$  is zero  
 R7: If  $p$  is near and  $l$  is far then velocity is low  
 R8: If  $p$  is far and  $l$  is far then velocity is high  
 R9: If  $p$  is far and  $l$  is near then velocity is low.

In the present implementation of the fuzzy controller the Center of Area method of defuzzification is used.

## SIMULATION RESULTS

The author applied the proposed fuzzy controller to the autonomous anthropomorphic wheeled mobile robotic platform moving in an unstructured environment with obstacles. A simulation example of a wheeled autonomous anthropomorphic mobile robotic platform is presented in Figure 5. The corresponding fuzzy control is implemented to perform tasks of obstacle and collision avoidance. The results of the simulation are shown in Figure 5 regarding the goal seeking and the obstacle avoidance mobile robot paths.



**Figure 5.** Example of an obstacle avoidance scenario, obstacle avoidance trajectory of autonomous anthropomorphic wheeled mobile robot platform.

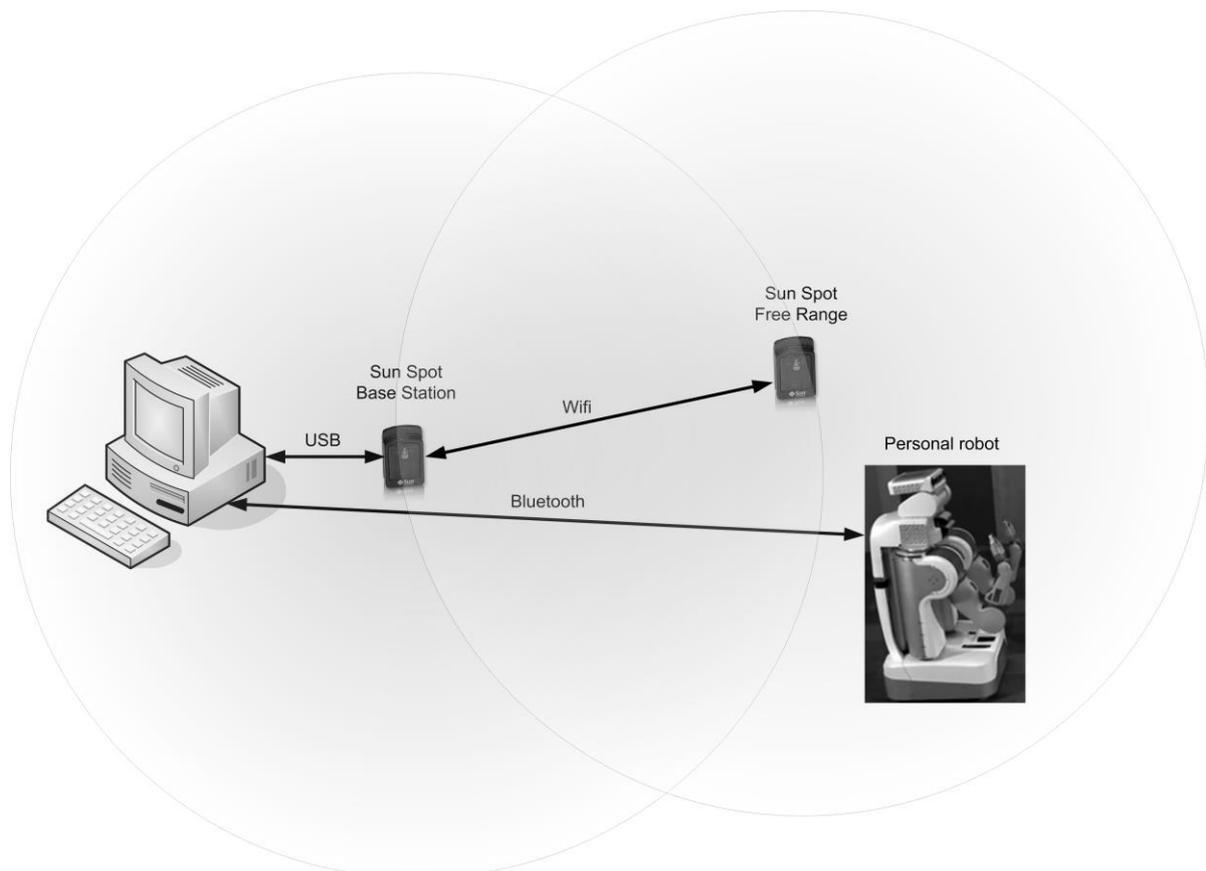
## **WIRELESS ROBOT-SENSOR NETWORKED SYSTEMS**

This article presents a wireless sensory control for mobile robot navigation. Wireless Robot-Sensor Networked systems refer to multiple robots operating together in coordination or cooperatively with sensors, embedded computers, and human users [26-33].

Communication between entities is fundamental to both cooperation and coordination and hence the central role of the networked system. Embedded computers and sensors are now ubiquitous in homes and factories, and increasingly wireless ad-hoc networks or plug-and-play wired networks are becoming commonplace.

Robots are functioning in environments while performing tasks that require them to coordinate with other robots, cooperate with humans, and act on information derived from multiple sensors. In many cases, these human users, the robots and sensors are not collocated, and the coordination and communication happens through a network.

In this article Sun SPOT-s (Small Programmable Object Technology) have been used to create remote control over a autonomous anthropomorphic wheeled mobile robotic platform, Figure 6. Sun SPOT is a small electronic device made by Sun Microsystems. The Sun SPOT is designed to be a flexible development platform, capable of hosting widely differing application modules. For this task 2 SunSPOT-s have been used from the development kit (Sun Microsystems, Inc. 2007).



**Figure 6.** Remote control system.

Sun SPOTs are programmed in a Java programming language, with the Java VM run on the hardware itself. It has quite a powerful main processor running the Java VM “Squawk” and which serves as an IEEE 802.15.4 wireless network node. The SunSPOT’s wireless protocol is Zigbee-based protocol. The Sun SPOT is designed to be a flexible development platform,

capable of hosting widely differing application modules. The SunSPOT base station is used to read the data from the free range SPOT and send its contents to the PC. The PC sends via Bluetooth the control signal to the autonomous anthropomorphic mobile robotic platform. Networked robots allow multiple robots and auxiliary entities to perform tasks that are well beyond the abilities of a single robot. Robots can automatically couple to perform locomotion and manipulation tasks that either a single robot cannot perform or that would require a special-purpose larger robot to perform. They can also coordinate to perform search and reconnaissance tasks exploiting the efficiency that is inherent in parallelism. Further they can perform independent tasks that need to be coordinated. Perhaps the greatest advantage of using the network to connect robots is the ability to connect and harness physically-removed assets. Mobile robots can react to information sensed by other mobile robots in the next room. Human users can use machines that are remotely located via the network. The ability to network robots also enables fault-tolerance in design. If robots can in fact dynamically reconfigure themselves using the network, they are more tolerant to robot failures. Finally, networked robots have the potential to provide great synergy by bringing together components with complementary benefits and making the whole greater than the sum of the parts.

## CONCLUSIONS

The article deals with the fuzzy control of autonomous anthropomorphic wheeled mobile robotic platform motion in an unstructured environment with obstacles. Further, it presents the wireless sensor based remote control of mobile wheeled robotic platform motion in an unstructured environment with obstacles using the Sun SPOT technology. The simulation results show the effectiveness and the validity of the obstacle avoidance behavior in unstructured environments and the velocity control of a wheeled mobile robotic platform motion of the proposed fuzzy control strategy.

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# ON-LINE INERTIA MEASUREMENT OF UNMANNED AERIAL VEHICLES USING ON-BOARD SENSORS AND BIFILAR PENDULUM

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## ABSTRACT

Identification of a dynamical model and its parameters is one of the fundamental problems in the field of robotics and system dynamics modelling. For the general situation of an object motion with six degrees of freedom (6-DOF), such as in the case of the Unmanned Aerial Vehicle (UAV), the key physical parameters are vehicle mass and moment of inertia. Even though UAV mass and its geometry/topology are easily obtainable, it is difficult to identify the inertia tensor considering that it is not measurable by static tests. This article presents a simple and effective method for on-line estimation of a rigid-body inertia based on a two-wire pendulum and an on-board integrated sensor system. Herein, the test subject (i.e. UAV) is suspended by two thin parallel wires in such a way to form a bifilar torsional pendulum about the vertical axis. Using on-board sensors from the UAV flight controller (FC) unit, the pendulum oscillations are recorded and processed in order to obtain trend-free and noise-free signals used in the final inertia estimation phase. The proposed identification algorithm is verified experimentally for two typical cases of suspended objects related to the UAV control box and a full UAV configuration.

## KEYWORDS

UAV, on-line moment of inertia identification, bifilar pendulum, IMU sensors

## CLASSIFICATION

ACM: D.1.1.

JEL: Z00

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## INTRODUCTION

For the purpose of UAV control systems development, knowledge about mathematical model of the system is required. In order to attain the requisite precision of such system model, all important parameters are needed to be known with sufficient accuracy [1, 2]. Since moment of inertia cannot be estimated through static tests, its identification could pose certain difficulties. For geometrically simple objects, inertia can be derived analytically or obtained from a model in CAD software. For more complex bodies such as the UAVs, equations tend to get more complex, which makes the calculation of inertia quite impractical, so it would be more convenient to estimate it from dynamical tests. Various approaches in [3-7] introduce identification of inertia based on measurements of the oscillation period of a bifilar pendulum. Although all these methods enable very precise results, they are based on offline analysis of measured data.

This article proposes the implementation of an on-line inertia estimation procedure using Kalman filter techniques and angle estimate from the inertial measurement unit (IMU) integrated inside the UAV flight controller (FC). In order to eliminate unwanted signal drift and noise from measurements, a recursive differentiating filter is used, cascaded to the low-pass filter implemented in the form of a scalar Kalman filter. Such processed signal is used to determine the period of a pendulum-suspended body oscillations, through detection and measurement of angle rise condition. As a final result, estimation result is based on analytical relationships of a pendulum oscillation period and inertia.

For the purpose of experimental identification of the UAV inertia, test setup is developed and assembled from two vertical beams forming the base of the pendulum, one horizontal beam and the test body (UAV) suspended via a two thin wires. When the test body is displaced from the initial condition and set free, a restoring torque twists it back toward the equilibrium position, and periodic motion is initiated, characterized by specific oscillation frequency.

The article is organized as follows. At first, a pendulum dynamics model considering the test body is introduced. Following by the design of an inertia estimation algorithm that includes the body deflection angle measurement, sensor drift compensation (detrending), a low-pass filtering to remove the sensor noise, and a pendulum oscillation period detection. Final section gives results of experimental verification for the proposed moment of inertia identification procedure and the concluding remarks.

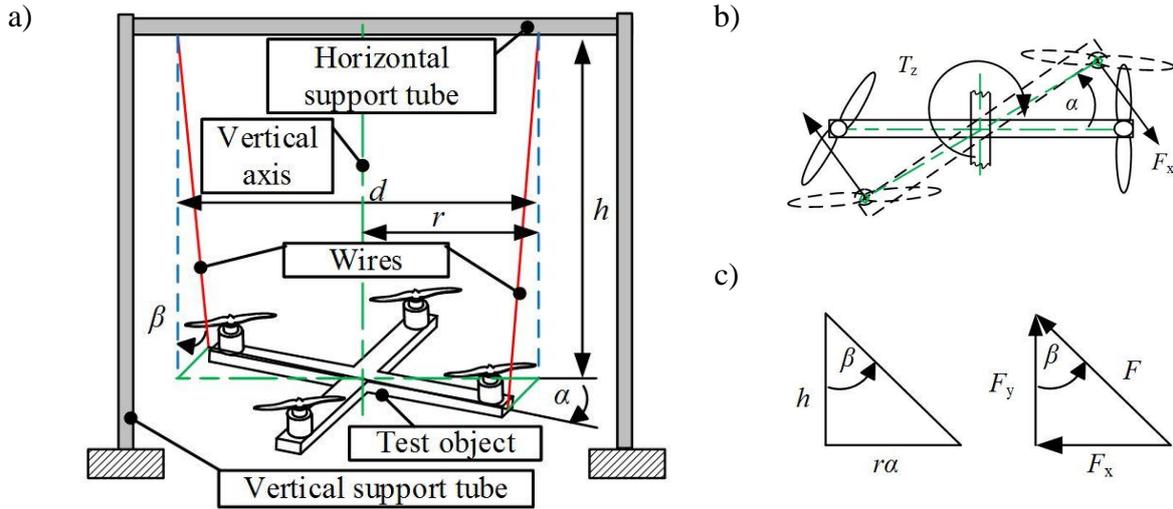
## PENDULUM MODEL

Dynamic modelling based on equations of motion is used to relate the measurable parameters of the pendulum's configuration to the inertia of the object suspended from the pendulum (see e.g. [3-7]).

For modelling purposes, some non-dominant physical factors are neglected as a trade-off between simplicity and estimation accuracy. The following assumptions are introduced: pendulum is centred around UAV Center of Gravity (CoG), wires are ideally parallel, and angular displacement of the wires from the vertical axis is negligible, wires are considered stiff and with negligible mass, displacement angle is kept small, there are no unbalanced vertical forces and rotation of pendulum is considered only about the vertical axis.

Figure 1a shows the following defined geometric constrains: distance between suspension wires,  $d = 2r$ ; length of wires,  $h$ ; twist angle around vertical axis,  $\alpha$ ; tilt angle due rotation,  $\beta$ .

From geometry it is possible to derive a kinematics relation by means of a simple trigonometric relationship. Further simplification is introduced by constraining oscillation



**Figure 1.** Bifilar pendulum: a) principal schematic, b) UAV deflections from normal and c) deflection angle representation related to body displacement and acting forces.

amplitude to small angles wherein  $\sin \beta \approx \beta$ . Thus, angle of twist  $\alpha$  can be related to rotation angle  $\beta$  via distance  $r\alpha$  obtained from arc length formula:

$$\sin \beta = r\alpha / h, \quad \beta = r\alpha / h. \quad (1)$$

Tension force in wires is derived from object weight. At stationary conditions (equilibrium), net torque  $T_z$  (Fig. 1) about vertical axis is zero and each wire holds half of object's weight.

$$F = \frac{1}{2}mg, \quad F_y = \frac{1}{2}mg \sin \beta, \quad F \approx F_y. \quad (2)$$

When the object is rotated around vertical axis by a small angle, a horizontal reaction occurs due to the tension in the wires, given by the following relationships:

$$F_x = \tan \beta F_y, \quad F_x = \beta F_y. \quad (3)$$

From Figure 1b, reaction torque is induced by horizontal component of the tension. Since each string produces equal forces, and thus total torque equals  $2F_x r$ , where:

$$F_x = \frac{1}{2}mg \frac{r}{h} \alpha, \quad T_z = \frac{mg r^2}{h} \alpha. \quad (4)$$

Using Newton-Euler formulation, with  $T_z = I\ddot{\alpha}$ , equations of motion are derived [6, 7].

$$I\ddot{\alpha} + \frac{mgd^2}{4h} \alpha = 0. \quad (5)$$

By solving this equation analytically, the solution for undamped oscillation case can be found in the standard oscillatory form:

$$\alpha(t) = c_1 \sin(kt) + c_2 \cos(kt), \quad k = \sqrt{\frac{mgd^2}{4hl}}. \quad (6)$$

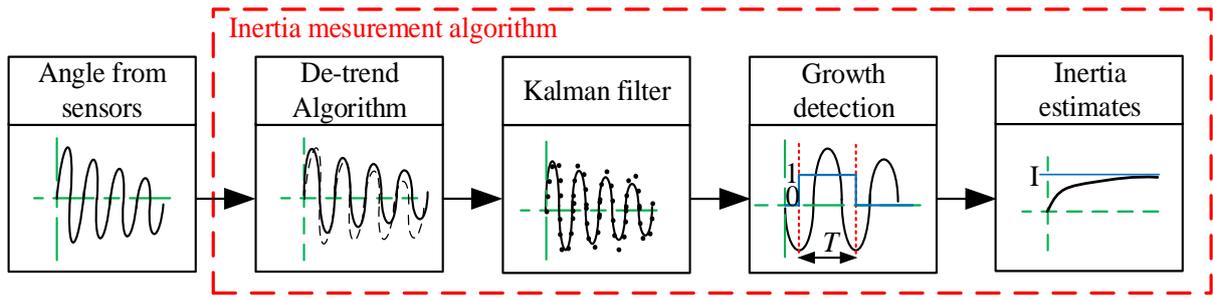
That oscillatory motion is characterized by the following period and frequency:

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{k}, \quad f = \frac{1}{2\pi} k. \quad (7)$$

## INERTIA ESTIMATION

The inertia estimation algorithm is implemented by using a Matlab Embedded Coder™, wherein estimator components are written as functions and are verified by computer simulations utilising Matlab/Simulink environment. By using Pixhawk Development Support, appropriate firmware for the flight controller (FC) is generated and uploaded. The angle information is obtained by attitude estimator embedded within the UAV [8, 9].

Figure 2 shows the individual components of the inertia estimation algorithm.



**Figure 2.** Inertia estimator algorithm schematic representation.

## MEASURING ANGLE OF OSCILATION

By utilising the integrated inertial MEMS sensors connected to the microcomputer, it is possible to determine vehicle attitude in the form of corresponding Euler angles. Moreover, by using the Estimation and Control Library (ECL) from Pixhawk PX4 flight controller, the angle is obtained by sensor fusion of magnetometer, gyroscope and accelerometer [8, 9]. Thus, obtained data is fed to the external computer through serial port by using External mode option for running the UAV model [9]. For that purpose, a custom firmware containing estimator application is generated and uploaded by using Matlab/Simulink Support library for Pixhawk Development [9].

## INERTIAL SENSOR DRIFT COMPENSATION

As discussed above, the oscillation angle is obtained from the IMU sensors integrated within the flight controller unit. These sensors provide fast and precise response, but may suffer from accumulated error, i.e. they may tend to ‘drift’. Due to aforementioned integrator properties of sensor dynamics, a constant error in acceleration measurement results in a linear (ramp) error in velocity and a quadratic (parabolic) error growth in terms of the UAV position. In order to remove (filter out) these drift effects, and, thus, to increase the robustness of inertia estimation, a recursive drift removal filter is introduced [10]:

$$y(k) = (1 - a_f)[x(k) - x(k - 1)] + a_f y(k - 1), \quad (8)$$

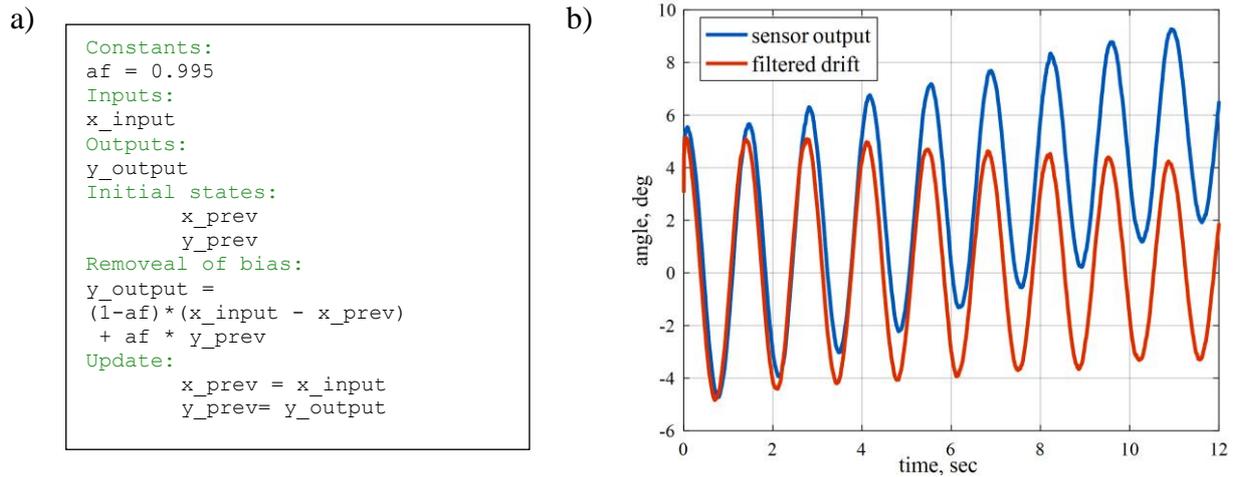
where  $y$  is the filter output,  $x$  is its input and  $a_f$  is the filter tuning parameter typically chosen between 0,9 and 1. The corresponding discrete-time ( $z$ -domain) transfer function of the detrending filter is given as:

$$H(z) = (1 - a_f) \frac{1 - z^{-1}}{1 - a_f z^{-1}}. \quad (9)$$

Figure 3a shows the pseudo code of the proposed detrending filter. Its effectiveness in terms of drift removal for typical IMU sensor measurements is illustrated by the results in Figure 3b. In particular, the deflection angle measurement linear trend superimposed to the actual pendulum oscillations is effectively removed, thus revealing the actual pendulum oscillatory movement in terms of displacement angle.

## DISCRETE-TIME SCALAR KALMAN FILTER

To filter out the measurement noise, a discrete-time scalar type Kalman filter (KF) is implemented. For the case of single-dimensional signals, such as the angle measurement, scalar Kalman filter may be convenient since it provides an optimal estimate of the state variable under assumption that measurement noise variance and state variable perturbations are known in advance [11]. The scalar KF is the special case of the more general matrix wherein,



**Figure 3.** a) Pseudo code of offset removal function, b) offset removal function response.

wherein the model parameters and measurements are scalar-valued [12, 13]. The filter operates by interchanging two characteristic phases: “predict” and “update”. The predict phase uses the state estimate from the previous time step to produce an estimate of the state at the current time step (a-priori estimate). In the update phase, the current a-priori prediction is combined with current observation in order to refine the state estimate. This corrected estimate is termed a-posterior state estimate [11, 14].

The internal state of the scalar Kalman filter is modelled by a random-walk process model [11]:

$$x_k = x_{k-1} + v_{k-1}, \quad (10)$$

which includes a Gaussian perturbation (noise)  $v$ , characterized by perturbation variance  $Q$ . The measurement noise is assumed to be Gaussian, and its variance  $R$  is derived from sensor technical specifications. The final scalar Kalman filter implementation is given by the following set of equations.

Predict phase:

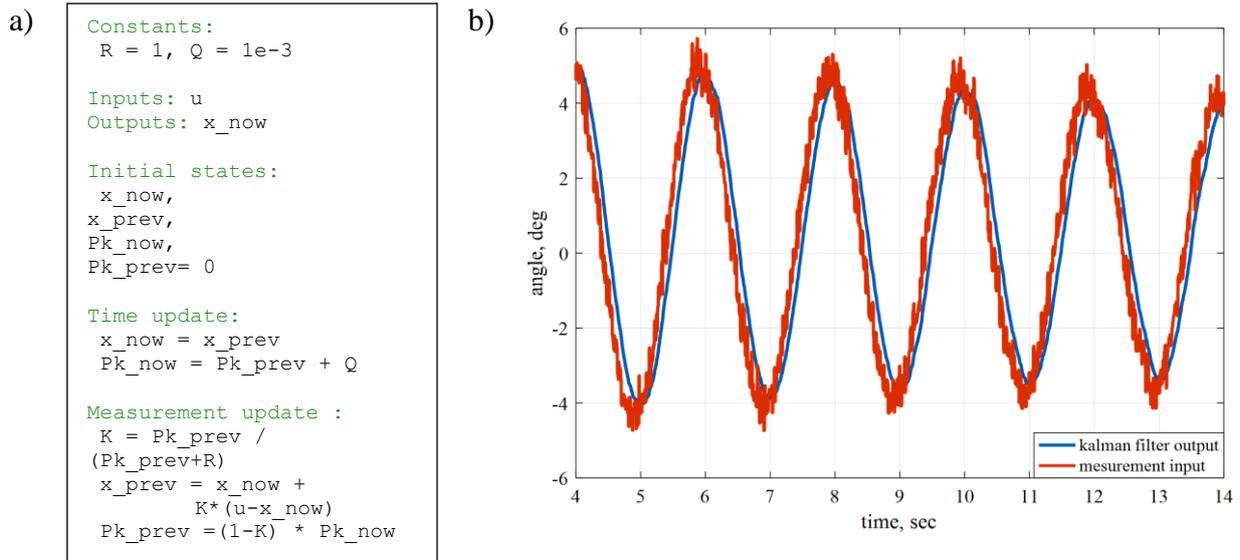
$$x_k = x_{k-1}, P_k = P_{k-1} + Q. \quad (11)$$

Update phase:

$$K = \frac{P_{k-1}}{P_{k-1} + R}, x_{k-1} = x_k + K(u - x_k), P_{k-1} = (1 - K)P_k. \quad (12)$$

Since the measurement noise variance  $R$  is assumed to be known in advance, the state perturbation variance  $Q$  represents the scalar Kalman filter tuning parameter. Its choice is usually a trade-off between parameter variations tracking ability and attenuation of noise.

Scalar Kalman filter implementation pseudo code is shown in Figure 4a. The filter response to an oscillatory signal with noise characterized by variance  $R = 1$  is shown in Figure 4b, for the case of the Kalman filter tuning parameter  $Q = 10^{-3}$ . The responses in Figure 4b indicate that the random-walk model-based scalar Kalman filter may be characterized by a certain response delay, but the general oscillatory behaviour is captured well.



**Figure 4.** a) Function pseudo code, b) filter response.

## OSCILLATION PERIOD ESTIMATION

Inertia estimation algorithm is based on the detection of oscillation rise and fall state with respect to time, and related oscillation period estimation. Angle evolution in time-domain can be separated into following stages: rise, fall, local maximum and local minimum. To detect if signal is in the state of increase (rise) or decrease (fall), a simple test algorithm is proposed. Input takes  $n$  samples from the inertial sensors and stores them in an array. When rise condition is detected a function initiates the counter that counts a number of samples until angle decrease condition is detected, wherein the counting is halted and the resulting number of counts is proportional to the oscillation period. By multiplying the counter final value and sample rate algorithm, the duration of rise condition is computed. If the last point is equal or higher than mean of first and second point, the angle has been in the state of growth, and the algorithm output is 1, otherwise the output is 0.

The proposed algorithm is given by pseudo code in Figure 5a, while the illustration of signal growth detection vs. oscillation plot is shown in Figure 5b. In this particular case, the angle growth detection initiates a counter when the input signal hits a drop point. The value of the counter multiplied by the sampling time provides an estimate of the oscillation period. Inertia is obtained based on the initial system parameters of the pendulum and the detected period of the oscillation. In order to obtain smooth (noise-free) estimation, the estimator output (inertia estimate) is further filtered by means of a narrow-bandwidth low-pass filter.

## INERTIA ESTIMATOR

From previously derived pendulum equations (4)-(6), expression for the moment of inertia in terms of oscillation period (or frequency) [3-8] can be obtained as:

$$I = \frac{mgd^2}{4h} \frac{T^2}{4\pi^2} = \frac{mgd^2 T^2}{16h\pi^2} = \frac{mgd^2}{16h\pi^2 f^2}. \quad (13)$$

A two second delay is introduced before each inertia value is recorded, in order to eliminate initial oscillations in the estimate, that may otherwise lead to error in estimation. For every calculated inertia, data is averaged and final inertia estimation is acquired. Figure 8 show pseudo-code implementation and the results of period detection and average inertia calculation.

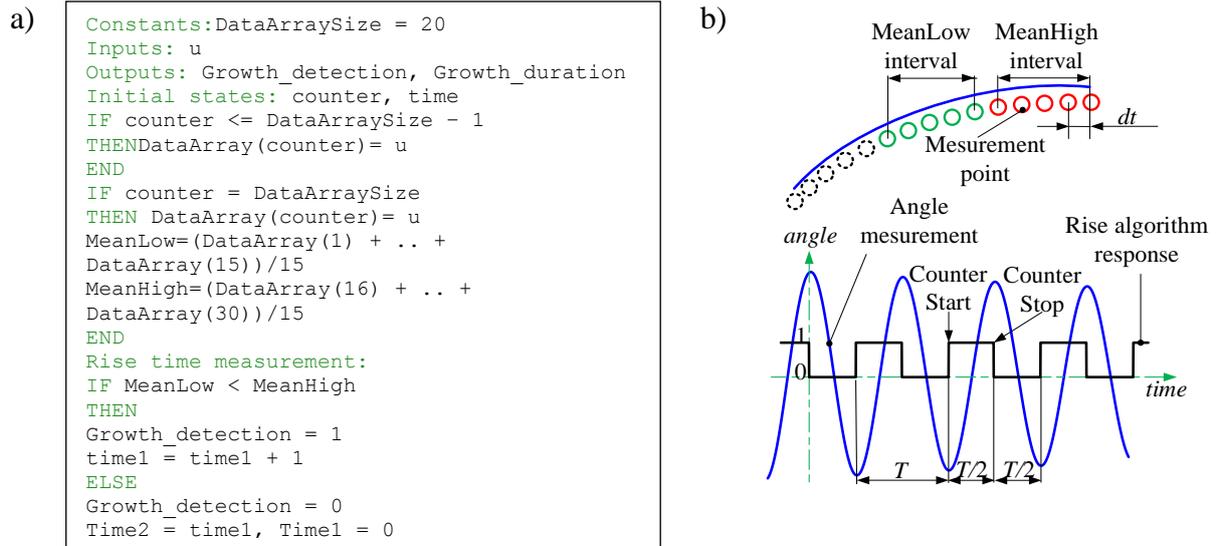


Figure 5. a) Algorithm pseudo code, b) response and period detection.

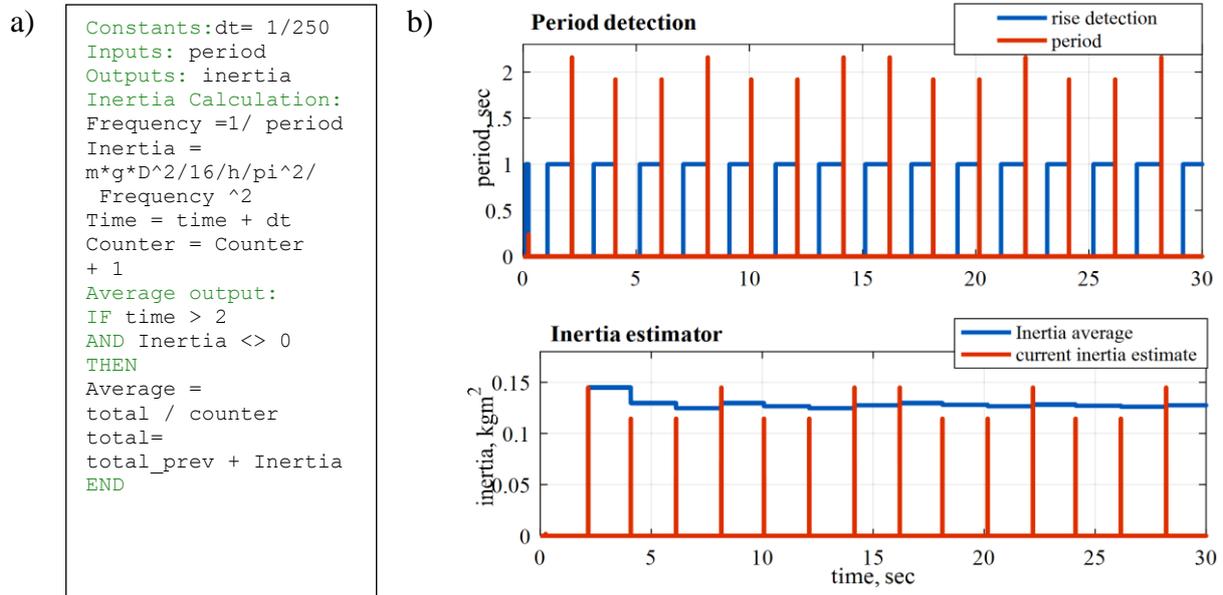


Figure 6. a) Algorithm pseudo code, b) response of Kalman filter, period detection and inertia estimation.

## MEASUREMENTS AND RESULTS

For the validation of the proposed inertia estimation method, a moment of inertia is calculated analytically. Measurements are taken for two test case scenarios including the control unit box (Fig. 7a), and the overall UAV system (Fig. 7b).

In the first test case, the box, inertia depends on width  $a$ , length  $b$ , height  $c$ , and the mass  $m$  with respect to the perpendicular axis to the rod, which passes through the middle of the rod (Fig. 7a) [15]. The flight computer and the box are centred with respect to the rotational axis, and, hence, the total inertia of the system about this rotational axis is calculated as:

$$I_{\text{box}} + I_{\text{flight computer}} = \frac{1}{12} m_b (a_b^2 + b_b^2) + \frac{1}{12} m_{fc} (a_{fc}^2 + b_{fc}^2). \quad (14)$$

Figure 8 shows the principal schematics of the experimental setup for the case of control unit box and the UAV suspended by the pendulum test wires. In the former case (Fig. 8a), the suspension point is at the edge of the box, while in the latter case (Fig. 8b), the overall UAV is suspended at the axles of two opposing quad rotor propellers.

The quad rotor inertia model consists of the geometric bodies such as the cross-beam, boxes and the cylindrical elements corresponding to motors and propellers (propulsion). Since the quad rotor UAV mechanical structure shows a high degree of symmetry, body inertia tensor can be reduced to a diagonal matrix [16]. Further approximation is to define the following parts: one cross-beam structure, modelled as two solid narrow cylinders fastened in the middle forming a cross, one electronics box and one FC, modelled as a rectangular parallelepiped, four motors, modelled as solid cylinders, four propellers, modelled as the flat cylinders (i.e. inertia of the rotating blade). The inertia of individual elements is listed in Table 1.

The total UAV inertia (Fig. 8b) is obtained by combining the inertia contributions of each body: frame inertia, electronics, flight computer, motors and propellers. Using parallel axis theorem and equations from literature [16], the following final set of equations is obtained for inertia values:

$$I_{xx} = \sum I_{\text{body}, x}, I_{yy} = \sum I_{\text{body}, y}, I_{zz} = \sum I_{\text{body}, z} \quad (15)$$

The setup is shown in Figure 9, wherein additional stability of the frame is assured by tripod elements at the ground level. Inertia is measured about vertical (yaw) axis. Undertaken measurements and the final results are shown in Table 2. The procedure is similar for other axes of motion, i.e. the body is rotated according to referenced axis of measurement. Figures 10 and 11 show the real-time inertia estimator plot for test cases a) and b). In first test case a logged signals stored on SD card are shown, and for the second test case, a real-time scope output using external mode is shown. Such live monitoring occasionally suffers from signal loss due to real-time execution of code. Because of limited memory external mode model is run as background task, but execution of code is not halted [9].

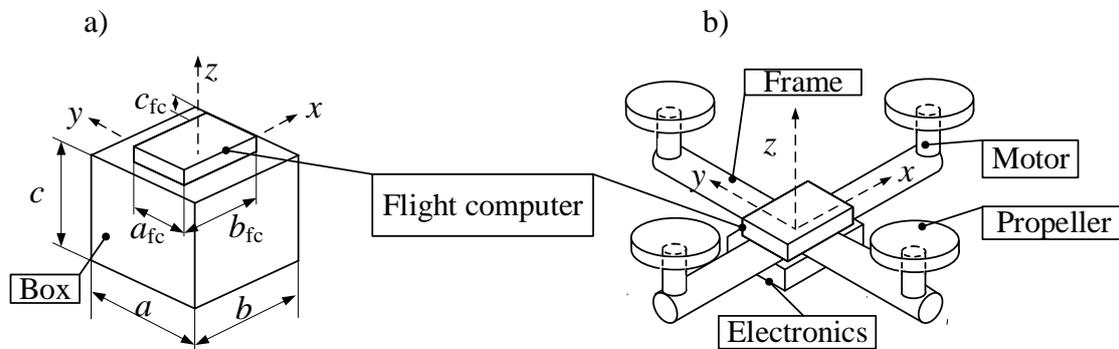


Figure 7. Inertia calculation for: a) box and b) UAV.

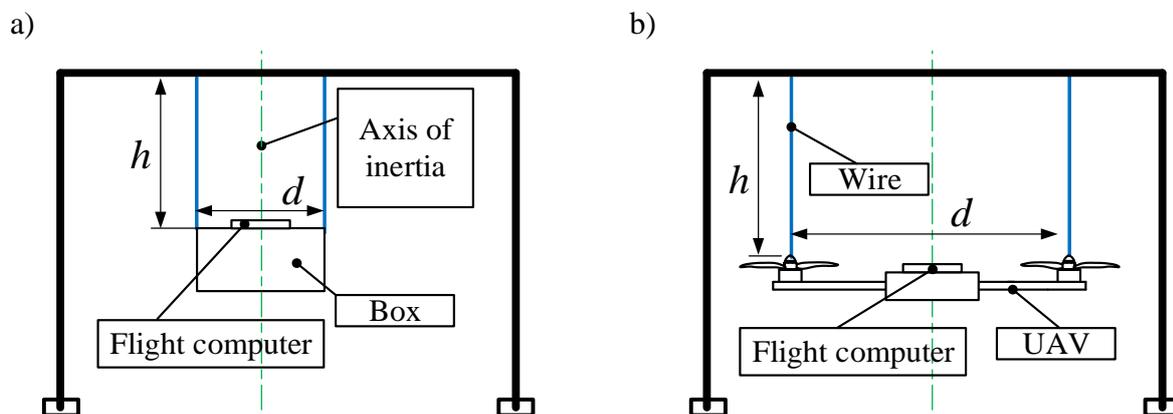
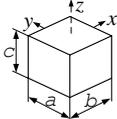
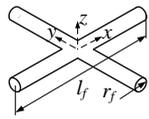
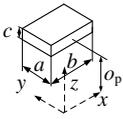
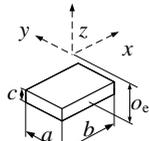
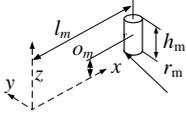
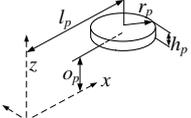


Figure 8. Test cases for inertia measurement: a) plate/box, b) UAV.

**Table 1.** Inertia calculation for test cases a) and b).

Part name	Formula	Geometry	Dimensions	Calculated inertia, kg·m <sup>2</sup>
Box	$I_x = \frac{m_b(b^2+c^2)}{12}$ $I_y = \frac{m_b(c^2+a^2)}{12}$ $I_z = \frac{m_b(a^2+b^2)}{12}$		$m_b = 376 \text{ g}$ $a = 50 \text{ mm}$ $b = 50 \text{ mm}$ $c = 50 \text{ mm}$	$I_x = 1.5667 \cdot 10^{-4}$ $I_y = 1.5667 \cdot 10^{-4}$ $I_z = 1.5667 \cdot 10^{-4}$
Frame	$I_x = I_y = m_f \left( \frac{r_f^2}{4} + \frac{l_f^2}{12} \right) + \frac{1}{2} m_f r_f^2$ $I_z = m_f \left( \frac{r_f^2}{4} + \frac{l_f^2}{12} \right) + m_f \left( \frac{r_f^2}{4} + \frac{l_f^2}{12} \right)$		$m_f = 454 \text{ g}$ $r_f = 14 \text{ mm}$ $l_f = 520 \text{ mm}$	$I_x = 0.0102968$ $I_y = 0.0102969$ $I_z = 0.0205047$
Flight computer	$I_{fcx} = m_{fc} \left( \frac{a^2}{12} + \frac{c^2}{12} + o_p \right)$ $I_{fcy} = m_{fc} \left( \frac{b^2}{12} + \frac{c^2}{12} + o_p \right)$ $I_{fcz} = m_{fc} \left( \frac{b^2}{12} + \frac{a^2}{12} \right)$		$m_{fc} = 38 \text{ g}$ $a = 55 \text{ mm}$ $b = 80 \text{ mm}$ $c = 18 \text{ mm}$ $o_p = 45 \text{ mm}$	$I_x = 8.755 \cdot 10^{-5}$ $I_y = 1.008 \cdot 10^{-4}$ $I_z = 3.245 \cdot 10^{-5}$
Electronics	$I_{ex} = m_e \left( \frac{a^2}{12} + \frac{c^2}{12} + o_e \right)$ $I_{ey} = m_e \left( \frac{b^2}{12} + \frac{c^2}{12} + o_e \right)$ $I_{ez} = m_e \left( \frac{b^2}{12} + \frac{a^2}{12} \right)$		$m_e = 380 \text{ g}$ $a = 200 \text{ mm}$ $b = 120 \text{ mm}$ $c = 35 \text{ mm}$ $o_e = 45 \text{ mm}$	$I_x = 0.00804685 \text{ kgm}^2$ $I_y = 0.00839545 \text{ kgm}^2$ $I_z = 8.5075 \cdot 10^{-4} \text{ kgm}^2$
Motors	$I_{mx} = m_m \left( \frac{r_m^2}{4} + \frac{l_m^2}{12} + o_m \right),$ $I_{my} = m_m \left( \frac{r_m^2}{4} + \frac{h_m^2}{12} + l_m + o_m \right)$ $I_{mz} = m_m \left( \frac{r_m^2}{2} + l_m^2 \right)$		$m_m = 55 \text{ g}$ $r_m = 14 \text{ mm}$ $l_m = 241 \text{ mm}$ $h_m = 39.7 \text{ mm}$ $o_m = 45 \text{ mm}$	$I_x = 1.2129 \cdot 10^{-4} \text{ kgm}^2$ $I_y = 0.00331575 \text{ kgm}^2$ $I_z = 0.00319984 \text{ kgm}^2$
Propellers	$I_{px} = m_p \left( \frac{r_p^2}{6} + \frac{h_p^2}{12} + o_p \right)$ $I_{py} = m_p \left( \frac{r_p^2}{6} + \frac{h_p^2}{12} + l_p + o_p \right)$ $I_{pz} = m_p \left( \frac{r_p^2}{3} + l_p^2 \right)$		$m_p = 2 \text{ g}$ $r_p = 127 \text{ mm}$ $l_p = 241 \text{ mm}$ $h_p = 4 \text{ mm}$ $o_p = 50 \text{ mm}$	$I_x = 1.1428 \cdot 10^{-5} \text{ kgm}^2$ $I_y = 1.2758 \cdot 10^{-4} \text{ kgm}^2$ $I_z = 1.2691 \cdot 10^{-4} \text{ kgm}^2$

**Table 2.** Results of measurements.

Test case number and subject	Estimated inertia, kg·m <sup>2</sup>	Calculated inertia, kg·m <sup>2</sup>	Difference, estimated vs. calculated, %
1. Box, z-axis	1,5407 10 <sup>-4</sup>	1,5667 10 <sup>-4</sup>	1,66
2. Box, z-axis	1,4734 10 <sup>-4</sup>	1,5667 10 <sup>-4</sup>	5,96
3. Box, z-axis	1,5584 10 <sup>-4</sup>	1,5667 10 <sup>-4</sup>	0,53
Average:	1,5242 10 <sup>-4</sup>	1,5667 10 <sup>-4</sup>	2,70
1. UAV, z-axis	0,0216	0,0316	31,65
2 UAV, z-axis	0,0285	0,0316	9,81
3. UAV, z-axis	0,0273	0,0316	13,61
4. UAV, z-axis	0,0281	0,0316	11,08
5. UAV, z-axis	0,0287	0,0316	9,18
Average:	0,0269	0,0316	14,87

The inertia estimates based on the pendulum period estimation show good consistency and low sensitivity to measurement noise, i.e. smooth steady-state estimates of moment of inertia are obtained by the proposed identification method.



**Figure 9.** Photograph of the UAV inertia measurement setup.

Box inertia about the particular axis of rotation is verified by means of a single experiment, due to high confidence in the relatively simple analytical expressions for box inertia (Table 1). On the other hand, for more complex body shapes, repeated tests would be worthwhile in order to establish the consistency of the experimentally obtained results, and, thus, to confirm the results of rather complex analytical calculations.

## CONCLUSIONS

This article shows the hardware implementation of a simple and effective method for on-line estimation of a solid-body moment of inertia, with particular application to the UAVs. Using inexpensive (and readily available) MEMS sensors and interface with computer, this method is portable to many hardware platforms. Moreover, by using automated on-line inertia estimation procedure, the effect of human error is excluded from the results.

Experimental results were presented for a two test cases, a homogeneous box and a 500 mm wide experimental UAV. Analysis of calculated and measured inertia was given for the purpose of verification of results. Developed method of inertia estimation has been experimentally verified, and it has been characterized by simplicity of implementation, adequate accuracy, high repeatability and low costs in terms of the hardware requirements. User interaction is limited only in the starting phase of measurement by imposing initial conditions (twist angle of  $5^{\circ}$ - $10^{\circ}$ ).

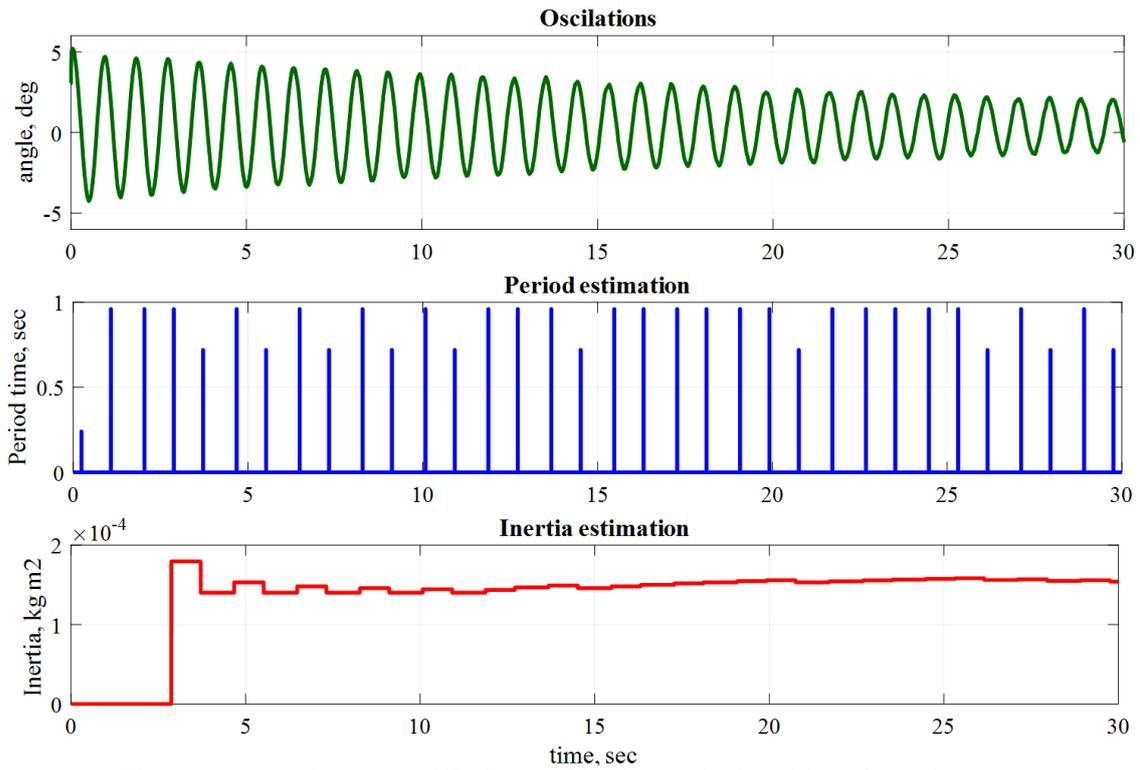


Figure 10. First test case, box – oscillations of body, period and inertia estimator response.

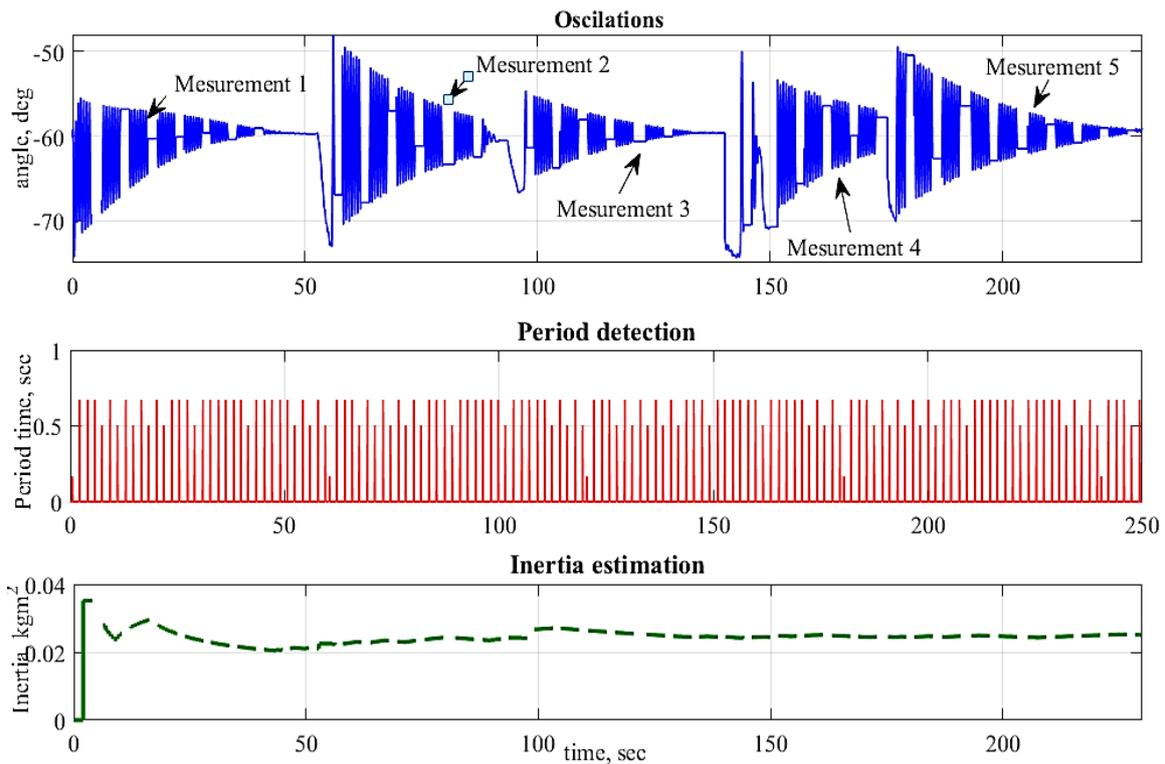


Figure 11. Second test case, UAV – oscillations of body, period and inertia estimator response.

## APPENDIX

**Table 3.** Abbreviations used in the text.

Notion	Abbr.	Notion	Abbr.
angular acceleration	$\ddot{\alpha}$	micro-electro-mechanical system	MEMS
box geometric measures	$a, b, c$	moment of inertia	$I$
box mass	$m_b$	moment of inertia of box	$I_{\text{box}}$
centre of gravity	CoG	moment of inertia of flight computer	$I_{\text{fc}}$
distance between suspension wires	$d=2r$	net torque	$T_z$
estimation and control library	ECL	output	$y$
filter tuning parameter	$a_f$	pendulum geometric constant	$k$
flight computer mass	$m_{\text{fc}}$	period	$T$
flight controller (computer)	FC	perturbation (gaussian noise)	$v$
force in x or y direction	$F_x, F_y$	six degrees of freedom	6-DOF
frequency	$f$	state perturbation variance	$Q$
inertial measurements unit	IMU	tilt angle due rotation	$\beta$
input	$x$	twist angle around vertical axis	$\alpha$
length of wires	$h$	unmanned aerial vehicle	UAV
measurement noise variance	$R$	UAV principal moments of inertia	$I_{xx}, I_{yy}, I_{zz}$

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# THE IMPACT OF ROAD TRANSPORTER DEVELOPMENT TRAJECTORY ONTO CARGO SAFETY AND SECURITY

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## ABSTRACT

This article attempts to reveal the general behavioural norms of cargo carriers, with a predominant emphasis on security issues. The security awareness level of road transporters has been found hugely dependent on management capabilities. Additionally, this poses a risk factor indicative of a shipment load's quantity and value. At a certain level of road transporter development trajectory, broad research delineates a sharp increase in security awareness, stemming from leadership recognition at larger companies. The results of the following research findings are significantly similar to various well-respected scientific theories which verify the hypothesis that the principal barrier to developing a company is a combination of a lack of management capabilities and an unwillingness to adapt to change.

## KEYWORDS

transportation, security awareness, management capabilities

## CLASSIFICATION

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## **INTRODUCTION**

The purpose of this article is to assess the measurement of the security awareness level of road carriers operating within Hungary. The topic seems relevant as the largest percentage of Hungarian foreign trade is handled within Europe and the proportion of road haulage corresponding with rail freight volumes is increasing. Consequently, most foreign trade shipments travel by road. The claims value arising from security incidents linked to road transportation in Europe has risen to millions of Euros per year [1]. This article deals with basic questions and correspondences of developing security awareness that could be a result of previous empirical experience, the size of a company and its adaptation to market demand. This article is the final section of a multiple article publication on this topic. Previous research findings [2, 3], revealed that security awareness is not a homogeneous factor, as the dynamics and awareness coincide with the size of a company. This document seeks to prove the relevant scientific literature and to present the findings and circumstances of the connected research. The hypothesis indicates road transporter security levels differ. However, it is possible to profile the carriers based on certain criteria. A further objective of this project is to verify the overall results with tendencies as described by proven scientific theories [4-7]. As a result, shippers may be able to concentrate their management efforts on pre-specified security risks by referring to general profiles. A carrier's security level is one of the basic pillars of supply chain reliability. Consequently, this affects the supply of resources to varying given manufacturing destinations. This approach verifies carrier value based on reliability rather than on service portfolio rendered.

## **STATE OF THE ART**

There appears to be a gap in scientific literature regarding the analyses and profiling of security attitudes towards road carriers. Much research has been carried out in the field of the supply chain management theory, examining a wide scope [8-13], which in part is relevant to this topic and provides a scientific background for an evaluation of carriers. Supply chains are examined in detail from multiple relevant publications. A literature overview and summary focusing on relationships in supply chains was published by Ványi [14], a similar approach aimed at logistic service providers was undertaken by Karmazin [15]. Another pertinent research field is the innovation and development of Hungarian companies [16-18]. A limited amount of Hungarian researchers have recently addressed cargo transportation issues [19]. An analysis of the latest trends and their effects on the transport industry has been worked out in detail. Bokor [20] defined reliability as paramount criteria, which comprises security and safety. His study is relevant to the road transportation industry as it systematically defines the selection criteria of transportation modes. In conclusion, the author anticipates a further increase in the use of road services. Bank et al. [21] reveal the profitability of Hungarian road carriers and project the forthcoming trends of the industry. Furthermore, logistic service providers have recently been widely researched in Hungary [15, 22], however road carriers have not. International authors have recently published findings regarding safety culture within the transportation industry [23]. There are multiple studies that deal with subcontractor vetting and selection criteria, defining security as a core element [24]. Personal competences, such as obtaining security and safety are hugely significant during the recruitment and selection process in human resource systems [25]. International studies relating to supply chain security awareness indicates that security is an integral element of managing business risks. Methodologies and systemised metrics have been developed [26] in order to establish a proper security design. Similarly, other researchers have focused on the impact of security culture on security operational performance [27].

The apparent lack of in-depth studies in the area of security awareness triggered the conduct of research pertaining to Hungarian road carriers. The basis of the original hypothesis was to question the incongruity of security awareness.

## **RESEARCH METHODOLOGY**

According to Rubin and Babbie [28], the advantage of a questionnaire is the ability to define the characteristics of large quantities, providing the possibility of a detailed analysis and leading to a good standardisation. The disadvantage of a questionnaire is the limitations caused by research participants' admissions and their validity [29].

This research addresses the analysis of information obtained from the carriers' feedback. Furthermore, it puts the findings of the interviews into context. The objective during the sampling was not to represent the entire Hungarian carrier market, as the primary focus was on companies that apply for subcontractor status at a logistics service provider within a given time frame.

### **QUANTITATIVE RESEARCH: SUBCO VETTING FORM<sup>1</sup> ANALYSIS**

During the quantitative stage of this research, statistical methods were applied to analyse the pre-audit data collection questionnaires sent from an internationally and locally well established and leading global logistics provider<sup>2</sup>. The practice of the company was to screen the new road carrier applicants prior to the start of any commercial business with a multiple aspect questionnaire. Feedback based on the questionnaires provided the structure for every personally conducted on-site audit, regardless of whether the company was being examined or re-audited for the first time or not. The auditing procedure was periodically repeated for already established partnerships or when a significant failure occurred. 101 questionnaires were examined during the time period of 2012 and 2014, regardless of whether the audited company was later accepted for business partnership establishment or not. The auditing company adopted the use of a new online subcontractor vetting and registration from 2014. This questionnaire globally unifies and defines its questions differently from the aforementioned, according to the screened parameters. Consequently, the data received could not be compared to the data obtained from the earlier period. The amount of 101 samples was sufficient enough for observations and for obtaining vital correspondences.

### **QUALITATIVE RESEARCH: INTERVIEW**

To be able to examine the results more deeply and ascertain a clearer understanding, the use of detailed interviews as a qualitative supplement for the questionnaires were conducted with the security and quality managers of the logistics company for verification purposes and to determine the reasons for varying results from the individual company groups. This interview to the double only served to strengthen the initial findings.

### **INTRODUCTION OF THE PARTICIPATING COMPANIES**

The research data and the returned Subco Vetting Forms were collected during the time period of 2012 to 2014. Parcel providers (Couriers), were excluded due to their irrelevant work dynamics and expectations. An additional criterion was that companies use pallet-based cargo transportation. Furthermore, the incomplete questionnaires were discarded. Altogether, 88 out of 101 vetting forms based on the criteria were considered. More specifically, re-auditing was conducted once for 66 companies, twice for 17 companies, three times for 4 companies and one company on four occasions. The total number of vehicles examined was 935, resulting in an overall average of 14 per company. The complete number of employees was 1322, with an average of 20 per company. The number of vehicles per company varied

between 1 and 85. The companies were predominantly registered as Hungarian Ltd's. However, eight companies were registered in Slovakia as Sro.-s and four as Hungarian self-employed or general partnership arrangements. During the crosschecking of the data some failures were detected. These comprised, zero vehicle units given, less truck drivers than trucks and more drivers than employees. Any inconsistent data was verified from other sources, such as the Opten<sup>3</sup> data pool or the companies own presentation materials.

## **RESULTS**

Researchers found that Hungarian companies significantly differ on using supply chain and risk management tools. Nagy and Venter's study in 2010 unveiled the existence of two separate company clusters, one developed and the other undeveloped [29]. Authors summarised that even the developed company cluster indicated a similar lack of middle values, in the adaptation of the individual tools. For information sharing and cost, performance measurement was more significant than the usage of material flow tools which denoted weakness in this cluster. During the first step of the data analysis the findings were not dissimilar to those of Nagy and Venter, in that road carriers were also categorised into two major clusters comprising two subgroups each.

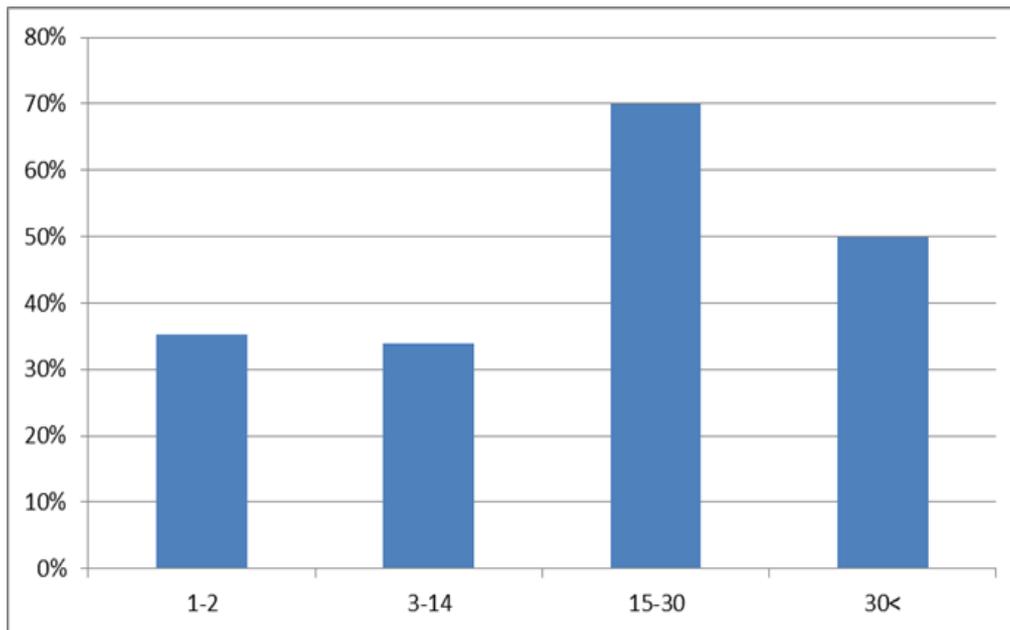
### **SPLITTING BASED ON COMPANY SIZE**

This section is based on the outcome of previous empirical research [2, 3], which provided a categorisation of the carriers based on their different security approaches. The most typical parameter of road carriers is the number of vehicles they operate. The target was to cluster the participants and unequivocally divide them based on their security awareness. In the course of earlier research conducted the following group's results showed significant correlation, therefore the rest of this article incorporates this method of grouping:

- Group 1: (companies with 1-2 vehicles), the driver is typically the owner or a close relative, administration is conducted by the same.
- Group 2: (companies with 3-14 vehicles), the owner very seldom drives the trucks. They started out by acting as a company, office employees are already present, but typically no owned premises exist.
- Group 3: (companies with 15-30 vehicles) generally have their own premises already, the company has good references and the owner is a competent skilled manager with a higher degree.
- Group 4: (companies with over 30 vehicles), financial investors often show up in the background, they carry particular weight within their region. The company is able to handle larger demands on its own.

The overall outcome of the earlier research regarding the security awareness measurement of road transporters is shown in Figure 1. The abscissa indicates the carrier categories grouped by the operated number of vehicles and the ordinate highlights the average compliance with the security audit.

The following section of this research article will test the rigour of the results obtained in multiple respects. The examination will adapt the use of three widely popular theories from three different professors. First, Drotter's conception defines the management development pipeline in the field of social science. Secondly, Christensen deals with the definition of different innovation types. Finally, as a foundational basis, Fischer's theory on the nature of supply chains has been incorporated. The three theories approach the topic from different angles which provide a full-scoped analysis for the observations. New research areas will be defined stemming from any new results.



**Figure 1.** Average security awareness level of the Hungarian carriers.

## RISK AND LIMITATION

There are multiple requirements for a company to be successful on the market, while at the same time maintaining financial stability. Adaptability, compliancy to the constantly changing demands of the market, the environment, competitors or labour market and the challenges caused by emergency situations appear to be the most pivotal attributes required. Additionally, the reaction time is a crucial element of success, which comprises the employee's education, experience and motivation towards each new challenge. A company's normal path to progression should challenge the organisation no differently from any other changes. Development is easily manageable for an organisation if it stays within its comfort zone. In other words, changes may be handled via a more intense use of the already given resources. It became correspondingly apparent that the number of trucks provided a snapshot of the carrier's organisational maturity. Interestingly, the development level correlated with the number of operated vehicles, as companies incorporating more than 15 trucks proved to be more developed. Transporters were divided into developed and undeveloped clusters having two subgroups each and the observation denoted that developed cluster members have a high security awareness level, whereas, underdeveloped group standards were unacceptably low. Moreover, security was heavily dependent on the company's management talent and human resource capabilities, which again seems relevant to the aforementioned attribute of adaptability.

## DROTTER'S MANAGEMENT PIPELINE

Drotter and associates defined a management pipeline [4], which shows the experiences and capabilities of the employees within an organisation. At a later stage, management values are added to the different levels of the pipeline [5]. The research indicates that the majority of the Hungarian carriers fell into the category referred to by Drotter, as a small business. In this case, the development of management capabilities mainly depends on the owner as they can foster or discourage any organisational and company development, such as using modern management tools, a flexible approach, applied values and the evolution of security awareness. Drotter's objective was to study the succession planning of large companies. Additionally, his approach is valid for individual management development stages too. Drotter defined six leadership passages which are defined as:

### **Managing others**

The initial management level starts when an individual's performance is not merited by their work alone, but through the responsibility for others job's. Usually high performers differ from the rest of the workers and obtain the possibility of becoming a first line manager. However, the difficulty they face is that success is no longer enough, as it is insufficient to complete their assignments thoroughly and in good time. Many do not recognise or implement desired behavioural and value-based changes. Newly promoted leaders have to accept the challenges required for their position. A carrier's first big developmental hindrance is to manage without acknowledging the need for change. The majority of transport entrepreneurs were initially simple drivers, who find it difficult to manage others. Individuals at this level must learn to value and practice the management role, as it is insufficient to merely tolerate it. This is the first level of a successful operational strategy, where it is imperative to enhance the capabilities of others and eventually delegate their own responsibilities to others.

### **Managing managers**

Leaders at this stage should only deal with management tasks. Additionally, it is a general expectation to have an understanding beyond their work description and to be able to interpret strategic questions. Furthermore, the education and training of first line managers should become a compulsory part of their scope of duties. Based on Drotter, this passage is connected with the sequential following passage and should not function separately in a small business. This is the highest level objective of the operational strategy where leaders should value change by focusing on productivity increase.

### **Functional manager**

Business unit leaders and support function managers such as the HR manager or the CFO of large companies fit this description. Leaders in this respect often face the challenge of managing new tasks with no direct relevant work experience. Functional managers should create teamwork and value its importance. They should participate in the creation of a long-term strategy which requires an understanding of how the given activity can be competitive on the market. Creating sustainable competitive edge capabilities should be the leader's most important task and governing value. This is the first level of business strategy.

### **Business manager**

Drotter's definition of a business manager contains elements that equate to the tasks of a highest positioned leader at a national entity of a multinational company. The position is referred to as the local CEO, general manager, national manager or managing director. As small companies are not on a regional or global level, the business manager has to perform the group and the enterprise manager roles too. It is a key position with multiple responsibilities. This way of thinking should be focused on margin and profit production capabilities. The business manager should be sensitive to the diversification of the production functions and should have a three to five year plan, observing a correct balance between future targets and the necessity of the present. This position is at the top end of the business strategy creation.

### **Group manager**

Drotter defines a multinational companies' regional manager as the group manager. Leaders who are successful at managing a business or a country come under this bracket, frequently later acquiring management of additional, similar businesses. It could be suggested that it is better to title the position as regional manager, because current organisational structures often fall under the matrix arrangement of multinational companies. Functional and regional roles

are often carried out by the same person. Drotter gives the most detailed job description at this level, delineating that a regional manager should possess an overview of a global business and strategy. The main criterion is that the group manager values other individual's success and accepts that they may receive the most recognition and appreciation, instead of themselves. The success of the employee is also the group manager's success. An additional target is to develop an adequate portfolio as part of a company strategy. Small businesses do not require this level of planning.

### **Enterprise manager**

An enterprise manager is the global number one leader of a company. Responsibilities include analysing quarterly reports, assessing the company's performance, determining and implementing long term strategies. A global leader must make three to four major decisions per annum while retaining an overall standard performance.

Drotter offers some further characteristics pertaining to this topic:

- To be successful at a certain level does not depend on past performance.
- If leaders cannot comply with the requirements of the given passage, the employees should leave or worse still, continue providing an ineffective performance.
- Significant numbers of small businesses fail to develop and implement new management levels, due to inflexible leadership.
- Failed transitions in leadership passages are typical due to reluctance to relinquish a manually steered leadership approach and eventually participants could not or did not want to adhere to the requirements and dynamics of the next management level.
- Financial investors often change the previous owner due to the reasons given above and hire a professional from a larger company.

There is a strong relationship between a company's development trajectory and the described pipeline based on the owner-manager's skills, education and experience. Drotter's findings could be defined as a transporters development barrier, eventually understanding the behaviour of companies comprising different fleet sizes. A company on an individual level, where the driver owns the company, adheres to different prioritised values than a large company, having multiple management levels. Findings indicated that the security awareness level is heavily indicative of the management capabilities of the owner and whether or not the leader observes and carries out the given passages, adapting to the required changes in governing values and their implementation. Furthermore, it could be firmly suggested that not anybody can be a successful leader where people-handling and intelligence skill sets are paramount. At a larger company an effective leadership pipeline should filter unsuitable candidates. However, in small businesses, the owners have to judge their own capabilities as to whether or not they are confident and able to progress to the next developmental stage. Incorrect self-assessment may result in underperformance or damage to a company. An additional temptation is the contented feeling of current success at all company sizes, providing a false confidence in performing well at the next level. Carrier size-based ranking may also mirror the leader's management capabilities. Given that a companies' general aim is to continuously develop, it could also be argued that an increase in a company's size should automatically follow. Expanding the size of a successful business is a typical methodology for gaining financial progress. The current status of the carriers is a mere overview of their development trajectory. Drotter's pipeline was aligned with the carrier groups defined earlier in order to test the credibility of the hypothesis.

Drotter's pipeline confirms the findings as outlined in Table 1. The small business' leadership levels are divided into four groups as are the carriers. Therefore, it was concluded

**Table1.** Drotter’s pipeline aligned with the carrier groups.

Level	Multi-national	Small business	Carrier	Strategy	Value	Security awareness
0	individual	individual	1 <sup>st</sup> group	operative	performance	instinctive/low
1	managing others	managing others	2 <sup>nd</sup> group		job allocation	subconscious/low
2	managing managers	functional manager	3 <sup>rd</sup> group	business	productivity	conscious/high
3	functional manager				competitiveness	
4	business manager	business manager	4 <sup>th</sup> group	company	profitability	Conscious /adequate
5	group manager				product diversity	
6	enterprise manager				sustainability	

that there is a strong correlation between the carrier’s management and their security awareness level. Transporters that focus on business strategy beyond the everyday load of operational tasks, reflect less organisational risk. A respect for security and safety first appears at this stage as a prerequisite for improved productivity and a competitive edge. The leader acknowledges the decrease of productivity related to security and safety incidents, regardless of its nature (operational, cargo, health and property safety and security). The carrier’s third group is most suitable for transporting sensitive shipments, due to the high security awareness and the size of the company. These carrier companies are the maximum size that constitute being transparent and manageable for a leader. It is typical to achieve an outstanding operational performance, but no excessive risk avoidance shows up at this level. However, in the fourth group, larger companies require more internal rules and predefined procedures resulting in an official declaration of risk avoidance. The predominant governing variable of this sized enterprise primarily focuses on sustainability and profitability, as highlighted in Drotter’s theory. Consequently, management does not consider the potential extra profit that could be gained from sensitive cargo for fear of uncontrollable financial loss. Despite a lower level profit margin, sustainability and assured profitability are paramount.

## THE IMPACT OF MARKET COMPETITION

The evolution of security is not solely contingent on organisational issues, but additionally by the market environment. On the condition that customers have a standard security related demand, the further determining factor is the service portfolio offered by competition. No companies can afford to fall behind its competitors in an open market environment. As was proven earlier, the creation of a business strategy and observing the market participants requires a decent company size, constituting above 15 operating vehicles per haulier. Based on findings from Clayton M. Christensen [6], companies generally focus on their high margin customers, who typically account for only a small portion of their total client portfolio. Services and products are primarily developed for this category with the majority of clients having to pay the innovation surcharges included into the product or service prices, despite the fact, that they would be satisfied with a cheaper, lower standard. Based on the theory of disruptive innovation, if the evolved market gap becomes large enough, the opportunity arises for a new competitor to enter the market with an inferior, cheaper product. The disruptive enterprise then attracts the masses, providing lower rates in hopes of a smaller but

predictable profit margin. According to this research, the attributes of the fourth carrier group are not dissimilar to disruptive innovators, while the third group's behaviour shares similarities with the affected disrupted market player. The third group stands out from the market through rendering special services, while larger companies are significant through size alone. This research did not indicate any similarities to Christensen's theory regarding the first and the second groups' behaviour of manufacturers consciously targeting consumer groups at the time of market entry, as the carriers did not provide an intentional competition strategy. The primary focus of the underdeveloped cluster was merely operational and financial, providing stability alone, while simultaneously neglecting strategic planning. Christensen's theory concurs with the results of this research, with the modification that carriers first announce business strategy, after reaching a certain maturity level. Existing strategies will continue to encourage market participants to adhere to a higher security standard and to increase security awareness as long as the market demands it. Consequently, the increased operating expenses will be the main hindrance to furthering profitable growth. Competitors operating at a lower cost and security level will appear disruptive and close successful business deals on favourable terms. Surprisingly, the excessive security level is disruptive to development at this stage. It could be argued that this is the reason for the decrease in quality of security tools and procedures in the fourth group, in contrast to the third carrier group. Additionally, carriers may not go bankrupt as suggested in Christensen's theory, but transform to serve the volume demand while lowering the service standard.

## **THE IMPACT OF SUPPLY CHAIN TYPES**

Supply chains vary based on product types. Fischer differentiates two types of product groups described as innovative and functional [7]. These differ in nature, requiring variant, specific supply chain management. Functional products provide predictable demand, a long lifecycle and narrow margins, requiring effective supply chains. This study shows that this kind of management can be best supported by large fleet operators, as the shipments are available in large standard volumes, pertaining to the fourth carrier group, preferring sustainability and stability as core values. A typical element of an effective supply chain is the continuous, cost-focused operation. The predetermined expectation was confirmed from the findings that large carriers may reduce their security related costs in order to meet the client's low cost expectations.

Fischer states that innovative products have an unpredictable demand, a short lifecycle and a high margin requiring a flexible supply chain, focusing on fast reaction times and an elementary demand for cargo protection. It is commonly accepted that flexibility requires extra management efforts and better operational execution capabilities. Research revealed that companies incorporating such qualities are mainly lead by educated, experienced people and the size of the company does not exceed what one person can transparently manage. Based on the aforementioned carrier groupings, the necessity of the third carrier group best serving customers with innovative products and a higher security level was confirmed.

No explanation for the security level of the undeveloped cluster was found. Both Christensen's and Fischer's theories do not appear to elaborate on the existence of the measured management levels as authors concur that carriers may already have a minimum security level by the time of market entry. The difference between these theories and the research propose further questions to be addressed:

- Who will cooperate with carriers entering the market without the compliance of a minimum security and safety standard? Should another market segment be addressed?
- Could the underdeveloped cluster be improved through another party's management surveillance?
- Is standardisation a future research area that could provide more transparency and manageability?

## **MATTER OF RELATIONSHIP**

Small carriers appear to approach business hugely on the additional premise of personal relationships. Good relationships, based on mutual favours rather than hard facts such as the price, are often considered. Adherence to compliance regulations seems to be beneficial by conducting business solely with multinational companies. Alternatively, from financial remuneration paid by the carrier to the dispatcher, many additional favours may be rendered, such as delays forgiven, lighter payloads, earlier payments or more favourable destinations assigned. In return, capacity availability during high season or flexible handling of mandatory driving hours is overlooked. In particular, small town carriers have close relations with local manufacturers in many ways, as these are often relatives, school mates or friends working together. A further influential factor is local patriotism, which may strengthen the usage of regional subcontractors giving extra value in the selection procedure. All these connections make changing the supplier very difficult and give the trucker a sense of job safety. The lack of competition may create issues due to underdeveloped security features. Furthermore, the rigour of Christensen's theory regarding the above has been proven due to discovering the real market demand for carriers entering the market with low security awareness.

## **PRESENCE OF INTERMEDIARIES**

Intermediaries in cargo transportation are known as freight forwarders, which are mainly non-asset based and their core business is transport organisation. Using a freight forwarder instead of a trucker directly has multiple advantages, such as increased knowledge level regarding routing, regulation, transport equipment, market conditions and experience with an extended number of carriers. An obvious explanation of the findings related to the underdeveloped cluster is the usage of intermediaries. Freight forwarders have an active subcontractor vetting system not dissimilar to the one examined here. As a result they provide a safe pool of selected carriers linked to the related transport order. Furthermore, they develop the carriers to their security standards by using economic power. The situation is advantageous for the trucker as well. New start-up carriers on the market can learn the business under the umbrella of a large intermediary accepting and developing security standards too. Not only newcomers work for forwarders, but additionally small family companies not willing to step to the next level. Another consideration in choosing a freight forwarder as a supplier is the capacity constraint arising from ad hoc freight conditions (destination, cargo size, volatility), whereas the added value is the availability of an evaluated carrier database. This competence can only be developed through an intensive workload over a long period of time, typically 2-3 years, including searching, interviewing, vetting, auditing and regularly re-auditing. Larger shippers normally gain such knowledge by themselves and may switch from using freight forwarders to the use of carriers.

## **IMPACT OF THE MANUFACTURERS SIZE**

As the carrier's size is related to their management knowledge, the same applies for shippers. Small or start-up manufacturers may lack cargo transport experience. Not knowing something usually leads to underestimation of its difficulty and the associated risks. Experiencing issues tends to generate learning curves. A combination of a small carrier cooperating with an inexperienced manufacturer may explain the underdeveloped cluster due to a lack of knowledge on both sides. These shippers normally do not recognise the necessity of involving larger carriers or freight forwarders and remain in partnership with similar sized truckers. In this instance, the shared objective of both parties is to manage operations. The educational level and the mutual understanding provide a convenient feeling of equality. Despite all that, companies producing low value cargo or transporting goods that are not subject to theft may

benefit from the partnership without issues for a substantial period of time. This approach indicates dissimilarity to Fischer's theory as the selection process of carriers does not seem dependent on the type of supply chain, but rather convenience and location.

## RAISING THE PERFORMANCE

As a summary of the above reasons, there are many grounds as to why security performance may remain poor:

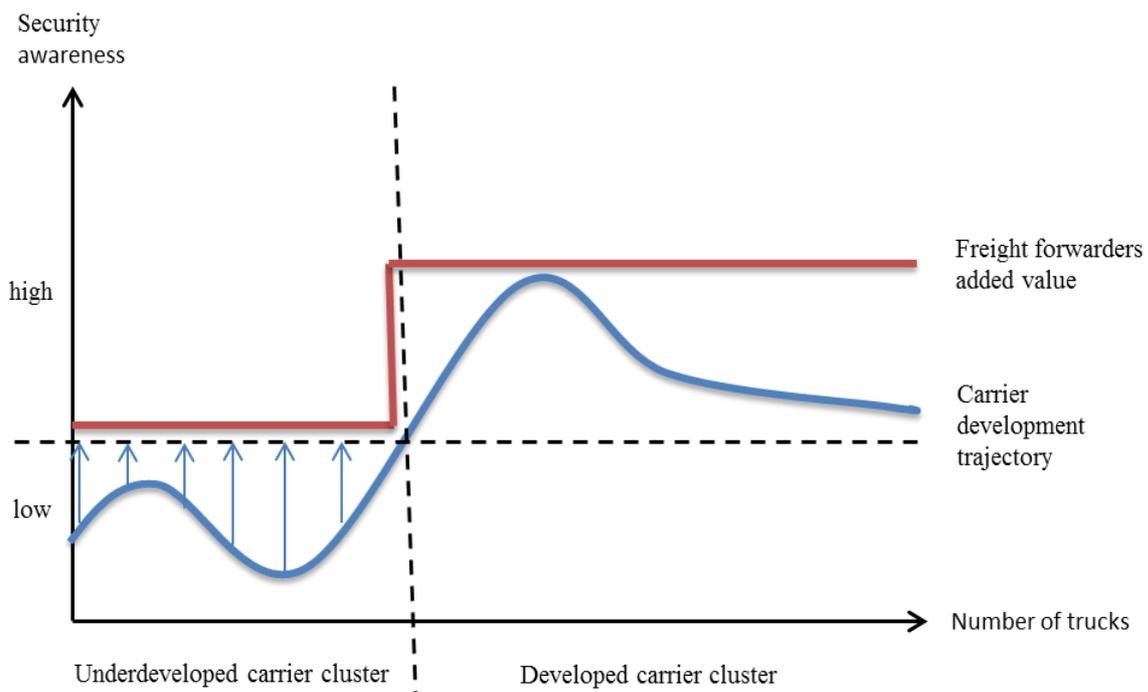
- Carrier did not develop relevant management skills,
- Handling low risk cargo,
- Lack of cargo transportation knowledge from the manufacturer's side,
- Lack of local competition.

Upgrading security performance to the minimum level is a vital requirement. As a reflection, carriers adopt to the market requirements during their development trajectory. It is possible to boost their learning curve in artificial ways:

- Create easily available and trackable overall standard requirements on the market. This should consist of standards for low risk and high risk cargo as well as reflecting other aspects such as the effective or innovative supply chain requirements. Comprehensive usage of standards may lead to a declining number of cargo crimes.
- Involving a well respected freight forwarder is an effective way to enhance security and to gain transportation knowledge at the same time.
- Involving a carrier with a higher security awareness level would automatically reduce the exposure to risk.

Figure 2 visualises the situation with and without involving external standards. The external standard can be defined by professional associations, large producers or a freight forwarder.

In Figure 2 the fluctuating blue line delineates the awareness level of carriers reflecting the findings presented. Additionally, the red line indicates the freight forwarders standard expectations, which are predetermined and examined via their subcontractor vetting activity.



**Figure 2.** Elevation of security awareness level involving freight forwarder.

Carriers meeting the standards will be awarded with transportation contracts, while others will not. There are three different scenarios illustrated on the chart.

- Underdeveloped carriers can be developed by the freight forwarders to the required minimum level.
- Developed carriers, especially those belonging to group three have the highest security awareness level, meeting the highest standards. In this case, the forwarders have little room left for adding value.
- Developed carriers belonging to group four do not intend to transport high risk cargo. Security level is decreased, making room for the forwarders to sell added value. However, the market does not really demand it.

Setting external standards would have the same impact on carrier's security awareness. A more in-depth research of manufacturers may possibly answer any open questions. It could be suggested that the results are merely partial elements of a more complex economical system, influenced by situational dynamics. Future research could focus on a more specific analysis of the overall environment.

## **CONCLUSIONS**

The research findings regarding Hungarian road carriers were tested against multiple science theories. Their statements were found relevant and hypotheses were proven in many aspects. The leadership pipeline theory created by Drotter and other authors confirms the carrier behaviour presented here. It could be stated that road carrier's management know-how corresponds directly with security awareness. Consequently, the risk factors associated with carrier company size, could well be standardised. Further analysis based on Christensen's theory led to modelling the carrier's product innovation stages during their development trajectory and the result supplemented the original theory, providing possible future research fields. Dissimilarities to his theory indicated that carriers could reach the company size required by volume businesses through natural development, resulting in being able to render the service parameters equal to the disruptive innovator. In this case, the disruptive innovator would not take over their place on the market, but merely influence the strategy.

Fischer's model of clustering supply chains was integrated successfully into the developed carriers' grouping research. Fischer's theory regarding supply chain management precisely reflected the carriers' third and fourth groups, but did not account for the behaviour of the first and the second groups. This indicates that the value of the transporter is dependent on the type of supply chain they are engaged with. Cargo transport, if well organised, accompanied with a conscious selection of management can provide a paramount element to the supply chain. Additionally, it is conclusive that a procedure selection failing to incorporate the above findings, may well result in insufficient carrier partnerships, differences in values, goals and basic understanding.

Not only soft factors, such as local patriotism, behavioural topics or relationship based business nature have been incorporated to strengthen the findings of this article, but also factual reasons were addressed. The latter comprised a risk of theft, the size and cargo knowledge of the shipper or the involvement of intermediaries. These elements provided sufficient explanation for dissimilarities noted to Christensen's and Fischer's theories. Additionally, this article revealed the area of adding a freight forwarder's value to cargo safety.

Further research of the examination of shipping companies' behaviour, management tools, the background dynamics of the discovered behavioural patterns and the entire overall system may be conclusive.

## REMARKS

<sup>1</sup>Short terminology of the excel sheet used for the subcontractor's vetting.

<sup>2</sup>Kuehne Nagel Hungary.

<sup>3</sup>Opten: information pool of company register data.

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# ON THE DEVELOPMENT OF INTELLIGENT RAILWAY INFORMATION AND SAFETY SYSTEMS: AN OVERVIEW OF CURRENT RESEARCH

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## ABSTRACT

The present article focuses on the research and development planning for innovative railway systems. Within such a general framework, the specific objectives of the research have been defined within the framework of a large Intelligent Railway System project in Hungary. Our theoretical research work at the university is combined with practical experience gained at the Hungarian State Railways. In the course of this research work, the development of an intelligent railway system has been investigated by leveraging on the fruitful cooperation between academic and industrial partners, in order to promote the application and integration possibilities of the development results, as well as the introduction of innovative components in the railway system. In such a context, this article discusses the research plan, preliminary and long-term expected results, sharing objectives and experiences with the aim of providing novel views in an extremely current and challenging field of research.

## KEYWORDS

railways, R&D, intelligent systems, critical infrastructures, safety and security

## CLASSIFICATION

APA: 4090, 4100, 4120, 4140

JEL: L92, R41, O18

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## INTRODUCTION

The age of the elements of the Hungarian railway system automation can be compared to that of a middle-aged human. This fact has great importance when considering the operation of the system and the scheduling of its necessary reconstruction. Such reconstruction work must be scheduled by railway professionals many years in advance, on the basis of the data collected manually and of their professional experience, taking into account the economic circumstances and the limited human resources available. The railway sector faces multiple challenges at a European level, too. Participants of the railway sector are now developing a more service-centred attitude by focusing on passenger demands, while also making changes in operation by using the latest results of continuous technological advancements. The European Committee aims to make railway transport the backbone of European transportation. In order to take this leading role, however, it is necessary to increase the competitiveness of the railway with regard to other alternatives. In case of long-distance journeys, these alternatives are the low-cost flights and international bus services in Europe. Meanwhile, some other players have appeared recently in the field of mobility further expanding the range of travel options. Public transportation must compete with new service providers using unconventional business models, such as various car-sharing companies [1].

Further objectives include increasing the safety of railway transport, ensuring high-speed transportation, developing transport management at a European level and achieving sustainability in transportation. In the long term, the railway system providing energy-efficient and reliable services can make part of a sustainable way of travelling which integrates various means of transport all over Europe [2-5].

Changing passenger demands generated by the transformation of the society – following the new trends in everyday life – call for the development of the railway industry and services, too.

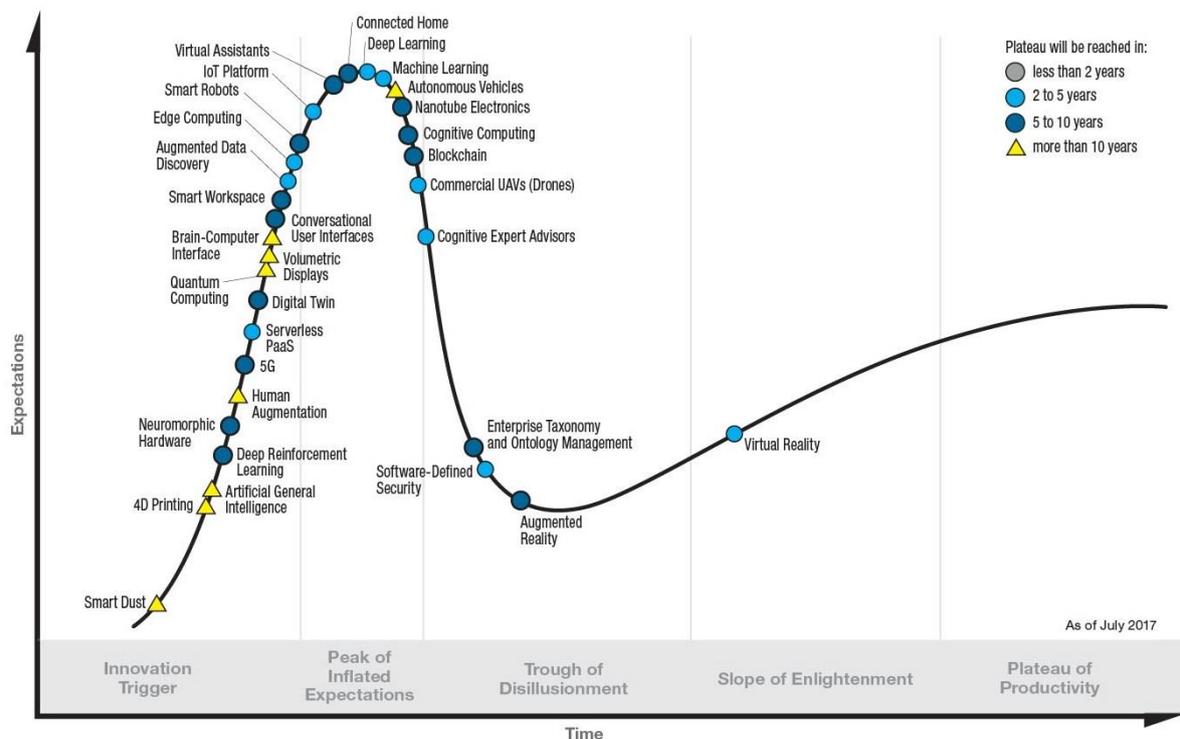


Figure 1. Gartner Hype Cycle for Emerging Technologies 2017, © Gartner [6].

Digitalisation has a significant role in this process, more specifically in the digital transformation of various transportation methods. Global technological concepts of

digitalisation, such as Internet of things (IoT), Big Data, Machine-to-Machine (M2M) communication, autonomous vehicles, robots and other emerging technologies are also gaining importance in the field of transportation (Fig. 1) [7-12].

For passengers, this means the provision of real-time travel information, a uniform ticketing system and increased automation in transportation [13].

## RESEARCH OBJECTIVES

The main topic of the research on intelligent railway information and safety systems can be made more specific by setting concrete objectives. Based on these objectives, the main lines of the research can also be defined. At the same time, the timeliness and significance of the topic of the research have also been pointed out [14, 15].

The fundamental research objective is to generalise, complete and expand the knowledge related to Intelligent Transport Systems (ITS), its various aspects and components that can be relevant from the viewpoint of railway systems (RITS – railway intelligent transportation systems [15]). The dominance of ITS in road transport can be disproved by modifying the common road-transport specific correlations [16-19].

In the course of the research, the following objectives have been set.

**Research objective 1:** Specifying and summarising the timely definition of railway automation through international research, supplemented by the definition of the intelligent railway system [20, 21].

**Research objectives 2:** Defining the concept of machine intelligence through research, and analysing its application possibilities in transportation, and more precisely, in the railway system [22-24].

**Research objective 3:** Finding and specifying the necessary recommendations, methods and procedures to define machine intelligence in the railway system [22-25].

**Research objective 4:** Analysing and defining the requirements of developing an intelligent railway system [22].

**Research objective 5:** Discovering and examining the possible methods of developing an intelligent railway system [22].

**Research objective 6:** Enhancing the protection of critical railway infrastructure by finding new methods and procedures. Examining the effects of new intelligent system elements through their applicability [22, 26, 27].

Railway automation refers to the widespread use of infocommunication systems, the integration of system elements into networks and the generation of a growing amount of data on the network level. In the increasingly complex railway system, human problem-solving processes are being transferred to computers in order to improve efficiency in operation.

The timeliness of the research can be illustrated by the ongoing developments, among which the example of the Mobility 4.0 initiative of the German railway must be specially mentioned. As a result of widespread digitalisation, German railway professionals managed to connect 200 trains into a uniform network. This will be further expanded in the future. Another result of this modernisation is that nearly 2 000 different parts can now be produced by 3D printing. According to plans, by the end of 2018, this new technology will be used to produce 15 000 different parts to ensure railway operation. The Deutsche Bahn group has 150 ongoing projects which involve the digitalisation of transportation [28, 29].

## RESEARCH METHODS

At the initial phase of the research, the general research methods have been employed. The method of comparison has been used to analyse the existing railway automation systems and to compare the concepts and practical examples presented in our earlier studies. Further methods used in this phase include the methods of reviewing the literature and providing definitions.

At the next phase, a number of experiments are conducted in the research field based on the use of empirical methods, with a view to the non-disjoint competence fields of the topic. These experiments allow the verification of the observed facts.

Finally, at the analysis of railway systems, the theoretical (primary) – logical (secondary) research methods are used. The conclusions of the hypothesis are made by synthesising the inductions drawn from the experience of individual cases and the deductions based on generalisations, by exploring the analogues between railway and other transport system applications (e.g. ITS) and by applying the scientific method of generalisation.

The research is aimed at finding answers to the following research questions (RQ) in accordance with the objectives defined previously.

**RQ 1:** What is the relationship between automation, digitalisation and the development of intelligent systems?

**RQ 2:** What does machine intelligence (MIQ) mean and can it be measured and defined with regards to railway automation systems?

**RQ 3:** Is there any relevance of the application of intelligent systems in the railway?

The main hypothesis of the research states that it is possible to develop a technical system within the railway system to ensure high-level automation and to achieve the goals of increased railway safety, high-speed transportation and the support, management and sustainability of transportation on a European level. This system must also make part of the European cooperative Intelligent Transport Systems.

## **OVERVIEW OF PRELIMINARY RESULTS**

This section provides a short summary of project plan and results of the preliminary study.

The answer to the first RQ: Intelligent systems are highly automated systems. The progress of digitalisation can be simply illustrated by such global phenomena as the M2M or IoT. As a result of these global technological changes, automated systems will be able to offer extended functionality and a higher level of automation; as a result, the autonomy of those systems can also be increased [22].

The answer to the second RQ: The intelligence of machine systems can be fundamentally measured, as it has been described by numerous international studies. The above-mentioned autonomy is only one of the indicators that are able to characterise intelligent machine systems. In the current research, further indicators (e.g. Self-Organizing, adaptation, observability, etc.) have been defined that can be used to describe the intelligence of railway automation systems [30].

The answer to the third RQ: As an example, the EN50128 standard for railway applications mentions AI (Artificial Intelligence) Fault Correction in the first place among applicable solutions. Since the issuance of the standard in 2011, research on machine intelligence has provided further results. We believe those results will have even greater significance in the implementation of intelligent railway systems in the future. It is enough to mention, for example, the application of an expert system that is able to provide prediction analysis of the throughput capacity of railway infrastructure in real-time [31].

The preliminary study that has been performed can be divided into two parts: theoretical (primary) research and logical (secondary) research.

The elements of the theoretical (primary) research included a systematic review of the literature, standards, EU Regulations, Directives and other acts, Technical Specifications for Interoperability, resulting in fact and relationship findings as well as knowledge improvements.

The elements of the logical (secondary) research included surveys with the participation of various players of the international railway industry (Operators, Infrastructure managers, Manufacturers, System integrators), resulting in speculative thoughts and railway-specific knowledge improvements.

The results, conclusions and statements are here provided by synthesising the results of the primary and secondary research by sub-topics (e.g.: railway automation, ITS, creating new definitions, implementing the methods of using machine intelligence in railway systems, defining the Hungarian Digital Railway Strategy, etc.).

According to their areas of application, the results of the research can be divided into two main categories. Results can be relevant both in academic/theoretical and in industrial/practical fields. The two-phase (preliminary) research provides the basis for the research, development and innovation projects currently underway at the university. Therefore, the results of our research will be directly used in the development project (“The Development of Integrated Intelligent Railway Information and Safety System”) lasting until 31/10/2020.

Academic/theoretical results: It can be expected that the work of the research, development and innovation team (approximately 80 people) at the university will bring long-term results in the research of the designated topic, in the field of disciplinary research, extending curriculum and applied research. In order to start the project, it is necessary to conduct preliminary studies, which provide bases for the research work at the university. The results described in the present article can be considered as the results of the preliminary study, as they can help to conduct the original research to gain new knowledge. The R&D (Research and Development) project of the university is directed toward a specific practical objective and will have final results that can be applied in the railway system.

Through the project organisation, a research and development team has been created which is able to deliver a project whose ambition is to be competitive at international levels. Until now, it has not been common to build a project organisation of this size around a single topic. Consequently, one of the significant results of our research in the academic world is that it has allowed the creation of this research infrastructure by specifying appropriate development plans and procedures. This means that, through the study of the appropriate system of rules, we have created the environment for a high-quality and highly-dependable (e.g.: SIL 4) development work. Our preliminary research has provided the bases for the start of more specific research projects, the circumstances of which had not been ensured at the university before. Our research, therefore, can be regarded as a kind of combination among meta-research, feasibility study and multi-year plan from the viewpoint of academic research.

Besides the main research and development staff, BSc, MSc and PhD students are also involved in the university project, working in 17 workgroups and 21 work packages. These students are expected to write various scientific studies and publications in this field, and the project offers topics for theses and dissertations, too.

Industrial results include a pilot project, product and technology development and at least one patent application.

The impact of our preliminary study can be of direct use for the industrial partners of the project (consortium members), as by the end of the experimental development based on this preliminary study, a marketable product will be created (i.e. project results feature a very high Technology Readiness Level). The expected product will go through a conformity assessment carried out by a notified body, and it must be tested in a pilot project and approved by at least one national authority.

The knowledge synthesised from the results of the preliminary studies, the original research and the practical experience will allow industrial partners to create new products, new devices, new systems and to introduce and develop new services, which, in the long term, will have an effect on multiple players of the railway industry e.g. Operators, Infrastructure managers, Manufacturers, System integrators, etc. The Integrated Intelligent Railway Information and Safety System and its various elements (e.g.: control device, HMI, etc.) can be considered as an example of such a new product. Furthermore, the protection of innovations and intellectual contents must be also ensured within the framework of this project.

## **SUMMARY OF THE RESEARCH PLAN**

The present research work provided the basis for a number of theses considering the development of interoperable railway system energy (ENE) and control-command and signalling system (CCS). These theses are discussed in view of the objectives and previously defined research questions.

**Thesis 1:** Automation and digitalisation determine the characteristics and implementation of intelligent systems [5, 15, 22, 30, 32].

**Thesis 2:** The intelligence of machine systems can be defined by using Smartness Indicators [5, 13, 14, 33].

**Thesis 3:** Intelligent systems have an important role in ensuring sustainability and the well-being of humans [5, 34].

**Thesis 4:** By increasing the adaptability of critical railway infrastructure, its vulnerability can be reduced [5, 16, 33].

**Thesis 5:** Adaptability can be achieved through the application of intelligent system elements [5, 33].

**Thesis 6:** In a complex, multi-level system, both distributed and centralised intelligence can be used [5].

**Thesis 7:** The criticality of system elements can be defined. The integration of the subsystems with the same level of criticality can ensure the flexibility of the system [5].

**Thesis 8:** Intelligence, as an element of the railway infrastructure, can be measured and planned [5, 13, 14, 16].

## **APPLICATION AND DIRECTIONS FOR FUTURE RESEARCH**

The current and expected research results of this project can be generalized to several fields of technical sciences, more specifically in military technical sciences, as well as in experimental development for military and defence purposes, as well as in various technological and technical innovations. Those research results can be used in particular in protecting critical infrastructures, and applying advanced processes and devices in the field of safety technology, technical safety and industrial automation, as well as in other related scientific and engineering field, whether railway-specific or not. Results include the development of new procedures, methods and technologies for railway automation, providing new procedures for:

- planning the implementation of the Intelligent Railway System
- elaborating a new general model of such system,
- describing and explaining the operation of intelligent elements in the railway system
- creating a new framework to measure the intelligence of the railway system [35, 36].

In general, the relevance of scientific results in the field of technical sciences can be determined by their roles in the industrial development. The above research results have not yet been put into everyday practice in the main railway environment. However, considering the current social changes in Europe and in the world, it is clear that further research work needs to be done in the field of transportation.

In recognition of the stated issues, the research performed at Óbuda University for several years has effectively supported the conceptualisation and planning phase of the railway system consisting of intelligent elements, namely IntelliSys-R (Intelligent System for Railway [22]).

## CONCLUSIONS

There is a growing demand for implementing various railway developments [37] on the bases of the latest scientific results. Intelligent transport systems will have to provide a holistic solution for all transportation means. The infrastructure of transportation (including its vehicles) can be considered critical from the point of social well-being; therefore its protection is of primary importance. Machine intelligence and smart systems are transforming our societies, and intelligent machines must also be used in the railway system, in view of the exponentially growing complexity of such infrastructural networks. Networking and communication-based operation will also have an increasingly important role in railway systems. A large amount of data [38] generated by the network-based operation will be automatically transformed into information allowing the basic forms of automatic operation in the railway system. In conclusion, the use of machine intelligence will lead to increased efficiency, sustainability and safety in transportation in the future.

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# THE ANALYSIS OF THE IMPACT OF DEPRECIATION ON EXTERNAL DEBT IN LONG-RUN: EVIDENCE FROM CROATIA

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## ABSTRACT

The impact of exchange rate changes in small open economies has been a widely researched topic for decades. According to economic theory and relevant research, depreciation can have a positive impact on the economy through an increase in exports, and a negative effect through decrease in an individual consumption. The aim of this article is to assess the impact of exchange rate depreciation on external debt in Croatia in the long-run. The long-run impact of depreciation on external debt in Croatia is assessed using Johansen cointegration approach. The results point to the existence of one cointegration relation. The long-run impact of exchange rate depreciation on external debt in Croatia is statistically significant and positive, what is in line with previous research and economic theory. The conducted analysis outlines the possible negative impact of depreciation on Croatian economy through the increase of external indebtedness, what could consequently decrease the wealth of all sectors indebted in foreign currency. Since Croatia is a highly euroised small open economy with high external indebtedness in foreign currency, this research provides captivating results for monetary and fiscal policy-making in Croatia. Therefore, as a result of the conducted empirical analysis, the exchange rate depreciation in Croatia is not recommended as the instrument of increasing export competitiveness due to current high external indebtedness in foreign currency.

## KEYWORDS

exchange rate depreciation, external debt, cointegration analysis, error correction model, long-run equation

## CLASSIFICATION

JEL: C32, C51, E63, H63

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## INTRODUCTION

The question of the impact of exchange rate fluctuations on overall economy has been the subject of much debate among academic researchers and economic policy makers for decades. On the one hand, Marshall-Lerner condition implies that exchange rate depreciation should foster economic growth through an increase in net exports [1]. However, on the other hand, the exchange rate depreciation leads to an increase of liabilities denominated in foreign currency. In case of accumulated foreign currency debt, currency depreciation might have overall negative effect on the economy. In many Eastern European economies, including Croatia, high external indebtedness in foreign currency is present. External debt represents a problem which is in focus of economic policy making for all European Union candidate countries, as well as for European Union member countries which are on its way of accession to Euro area, such as Croatia.

Since the implementation of Stabilization Program in October 1993 by the Croatian government, there has been comprehensive discussion about managing the exchange rate level, taking into account high level of import dependency, high degree of openness, high level of external debt and extremely euroised financial system [2]. Nevertheless, the Croatian National Bank achieves its primary goal, namely price stability, by maintaining the stability of Croatian kuna to euro. The current exchange rate policy serves as a nominal anchor of monetary policy. The research of impact of depreciation on external indebtedness is important for many reasons. Croatia is small economy with high import dependency.

The criteria for accession to Euro area is referred to as convergence criteria, the so-called "Maastricht criteria". These criteria relate to the government budget deficit, public debt, inflation, interest rate and exchange rate. Inflation rate, which implies that the average rate should not be higher than 1,5 percent in relation to the three the most stable EU member states in one-year period being taken for evaluation [3]. Considering Croatia, the annual inflation rate measured using consumer price index was 0,2 % in 2016 with respect to 2015 [4]. Furthermore, the exchange rate by which a member country must participate in the Exchange Rate Mechanism (ERM II) of the European Monetary System continuously over two years prior to the year in which the exchange rate is reviewed. Croatia is accomplishing mentioned two monetary conditions, while fiscal criteria are not achieved yet. Two fiscal criteria that concern the public balance of the general government sector and the general public debt expressed as GDP ratio, what represents the sustainability of public finance policy. Regarding the first criteria, public balance of the general government sector must not exceed 3 % at the end of the previous financial year. In Croatia, according to [5], the current account deficit in 2016 was 3.8 % of GDP. Second fiscal criteria explain that public debt must not exceed 60 % of GDP at the end of the previous financial year. In Croatia, public debt was 83,7 % of GDP [6] in 2016.

Since the external indebtedness is the ongoing problem of small open Eastern European economies including Croatia, the research of depreciation effects should include external debt in order to provide broader insight into effects of depreciation. Considering Croatia, the competitiveness and wealth effect as consequence of real exchange rate on Croatian economy is estimated in [7] using linear regression modelling. Mentioned research firstly empirically analysed the competitiveness effect, namely the impact of changes of the real exchange rate on net exports and additionally the wealth effect, namely the impact of changes in wealth on consumption as a result of depreciation, was analysed. The analysis pointed to the conclusion that in spite of the fact that the increase in the real exchange rate leads to a relatively greater increase in net exports than the reduction of wealth causes a relative reduction in consumption, the depreciation of Croatian kuna is not economically reasonable due to the potential risks of extremely high external debt denominated in foreign currency. The impact

of real depreciation on net exports in Croatia is analysed in [8] using Johansen cointegration approach and the authors conclude that there is long-run positive impact of depreciation on trade balance. Both [7] and [8] discussed the impact of depreciation on Croatian economy, and theoretically mentioned the negative impact of exchange rate depreciation on external indebtedness. However, this research aims to analyse the long-run impact of exchange rate fluctuations on external debt in Croatia. The mentioned impact has not been empirically analysed in Croatian literature prior to this research. Obtained results will offer a basis for the comprehensive analysis of the impact of depreciation on Croatian economy.

The conclusion of [7] is that there is positive impact of depreciation through competitiveness effect on net export and the negative impact through wealth effect on consumption. However, this research contributes to the existing literature by employing Johansen cointegration approach to estimate the impact of depreciation on external debt in long-run, what has not been previously assessed in Croatian literature. The results of this research are interesting both for monetary and fiscal authorities in Croatia, since exchange rate policy is conducted by monetary authorities, while the public part of total external debt is managed by fiscal authorities.

In line with previous research and economic theory, the following research hypothesis is stated: The nominal exchange rate depreciation increases the external debt in Croatia. The nominal exchange rate is used in empirical analysis since monetary authorities can affect nominal exchange rate, while real exchange rate depends additionally on domestic and foreign price level. In this article, the emphasis is on the analysis of the impact of often recommended nominal depreciation on Croatian external indebtedness. Thus, nominal exchange rate is more appropriate than real exchange rate in order to empirically assess the adequacy of conducting exchange rate policy in Croatia.

## LITERATURE REVIEW

According to Marshall Lerner Condition, real depreciation makes domestic goods and services relatively cheaper related to foreign goods and services which causes increase of foreign demand and therefore increase of domestic export [1]. In addition, real depreciation makes foreign goods and services more expensive what boosts domestic demand for domestic goods and decreases imports. Small open economies worldwide are dealing with the problem of high import dependency. However, the depreciation as potential instrument of stimulating export competitiveness can initially cause short-run negative impact on economy which can be explained with J-Curve effect [1, 9]. According to economic theory, wealth effect is explained as an increase in exchange rate which increases the wealth of private sector and thus consumption. But if the private sector has debt explosion, the exchange rate depreciation might lead to an increase in foreign debt denominated in the domestic currency [9]. Consequently, depreciation might affect the reduction of consumption, which is the most substantial component of Croatia GDP. Therefore, the exchange rate depreciation can have twofold impact on the overall economy.

Various empirical studies have analysed the impact of exchange rate on net exports and gross domestic product and they estimate the positive impact of depreciation on competitiveness through increasing net exports. In their analysis of New Zealand external debt, [10] recommended exchange rate depreciation. The mentioned research suggested exchange rate depreciation in New Zealand since external debt is denominated primarily in New Zealand dollars. Hence, depreciation could have a significant and positive effect on GDP through increased export competitiveness. The empirical examination of sustainability of exchange rate and external debt policies in 5 MENA countries (Tunisia, Morocco, Egypt, Jordan and Turkey) is conducted in [11] using unit root and cointegration test. The conclusion of [11] is that although Egypt accumulated enormous external debt, profitable decision was to shift to a

flexible exchange rate regime in 2001. Indeed, devaluation of Pound in Egypt has stimulated export competitiveness and therefore decrease current deficit. Similarly, devaluation of Lira in Turkey and exchange rate floating have increased the export competitiveness and reduce pressure for servicing enormous external debt. On the contrary, Jordan continued to follow a fixed exchange rate policy to US dollar because any exchange rate depreciation would increase external debt. Moreover, the fiscal policy in Jordan should foster reduction of external debt. Morocco and Tunisia run a harmonized fiscal and monetary policy and consequently successfully manage the external debt, but also the exchange rate through which they benefit through export.

The research of [12] estimates panel ordinary least square regressions with fixed and random effects and conclude that external debt is undoubtedly related to budget deficit, current account deficit and exchange rate depreciation, but the connection between external debt and these three components is more significant in debt trap countries (India, Indonesia, Nepal, Pakistan, Sri Lanka and Thailand) than in non-debt trap countries (Bangladesh, Fiji, Korea, Malaysia, Myanmar, Papua New Guinea, Philippines and Singapore). Moreover, [13] use a standard two-sector dynamic stochastic general equilibrium (DSGE) model for an emerging economy markets came up with conclusion that exchange rate depreciation increases foreign borrowing through nominal and real interest rate. The cointegration approach is used in [14] and authors outline that there is a long-run cointegrating relation between the exchange rate and external debt in Pakistan. Research mentioned points to the result that the increase in external debt depreciates the real exchange rate. The effect external debt on exchange rate is analysed in [15] analysed using linear regression model. Pearson correlation coefficients for various components of external debt are specified, but the most prominent subject is public external debt which has considerable impact on fluctuation of exchange rate. It is also shown that the depreciation of the domestic currency leads to an increase in external indebtedness.

## **THE EMPIRICAL ANALYSIS OF THE IMPACT OF REAL EXCHANGE RATE ON EXTERNAL DEBT CROATIA**

### **DATA AND METHODS**

Monthly data on both gross external debt and nominal effective exchange rate indices are used in empirical analysis. Data on gross external debt are available at [16] and refer to the sum of public sector external debt, publicly guaranteed private sector external debt and non-publicly guaranteed private sector external debt. Data on indices of nominal effective exchange rate of the kuna, 2010 = 100 are available at [17]. Index is calculated a weighted geometric average of the index of bilateral nominal exchange rates of the kuna against the selected currencies of the main trading partners [17]. The seasonal component is present in both analyses time series and seasonal adjustment is conducted using X-13 ARIMA SEATS adjustment method provided by [18]. Thus, seasonally adjusted logarithmic values of nominal effective exchange rate (denoted by *LE\_SA*) and seasonally adjusted logarithmic values of external debt (denoted by *LD\_SA*) are used in empirical analysis.

**Table 1:** ADF unit root test *t*-test statistics for selected variables in levels and first differences. Source: Author's calculation using EViews 9.

<b>Variable</b>	<b>Constant</b>	<b>Constant and trend</b>	<b>No deterministic components</b>
LE_SA	-1,8872	-1,7860	-0,6637
LD_SA	-3,2818	1,1720	2,4186
$\Delta$ LE_SA	-11,9903*	-12,1293*	-11,9673*
$\Delta$ LD_SA	-4,8887*	-13,9347*	-3,2091

\*denotes the stationarity of time series at 1 % significance

The null hypothesis of a unit root cannot be rejected for both selected variables in levels. However, it is not rejected for variables in the first differences and it is concluded that time series are stationary in first differences. Thus, both time series are not stationary in levels and stationary in first differences at 1 %. If a linear combination of non-stationary variables is stationary, the variables are cointegrated [19]. The existence of cointegration between *LE\_SA* and *LD\_SA* is examined in the next chapter.

## RESULTS OF COINTEGRATION ANALYSIS OF EXCHANGE RATE AND EXTERNAL DEBT IN CROATIA

Johansen's cointegration approach is used to assess the existence of cointegration among selected variables. Cointegrated variables are related in a long-run, thus the long-run equilibrium exists. However, expression "equilibrium" is used in a different manner by econometricians and economic theorists. Economic theorists refer to the equality between actual and desired state of economic variables. In econometric sense, "equilibrium" refers to the long-run relationship of non-stationary variables. Therefore, for cointegration existence among variables, it is not necessary that long-run equilibrium is the result of a market mechanism or behavior of individuals [20].

Trace and maximum eigenvalue test are used to determine number of cointegration vectors. When the null hypothesis is rejected for first time, the conclusion about the number of cointegrating vectors is brought. For further information about trace test and maximum eigenvalue test see [19]. Results of both tests are presented in Table 2.

**Table 2:** The results of the trace test and the maximum eigenvalue test. Source: Authors' calculation.

Hypothesized number of cointegrating equations	Eigenvalue	Trace statistic	0,05 Critical value (trace statistic)	Max eigenvalue statistic	0,05 Critical value (max eigenvalue statistic)
0*	0,2554	34,9714	20,2618	27,4210	15,8921
1	0,0780	7,5504	9,1645	7,5504	9,1645

\*denotes rejection of the hypothesis at the 0,05 level

Both conducted tests indicate that cointegration between exchange rate (*LE\_SA*) and external debt (*LD\_SA*) is present at 5 % significance. Based on estimated cointegrating vector, the long-run equation with associated *t*-values in parentheses is given by (1):

$$LD\_SA = 7,827 + 0,624LE\_SA \quad (1)$$

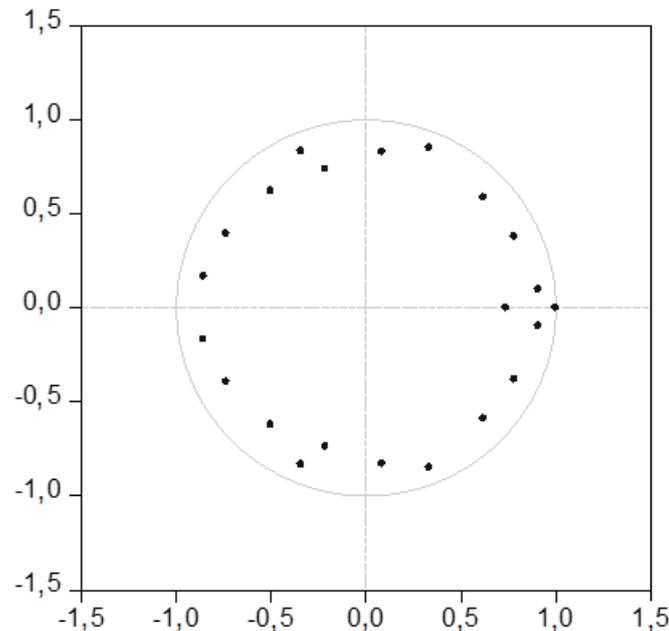
(6,611) (2,445)

In long-run nominal exchange rate has positive statistically significant impact on external debt in Croatia. In other words, the estimated model points to conclusion that increase in nominal exchange rate, namely nominal depreciation, causes an increase in external debt.

The error correction term (ECT) is equal to  $-0,1782$ , with *t*-statistics equal to  $-3,8384$ , pointing to the significance of ECT. The negative sign of ECT indicates that variables return to long-run equilibrium. In every month, 17,82 % of disequilibrium is corrected and therefore external debt returns to the equilibrium level for 5,5 months.

Furthermore, residual diagnostics tests are conducted. White heteroskedasticity test  $\chi^2$  statistic equals 116,7435 with associated empirical level of significance equal to 0,7108. Therefore, the null hypothesis of homoscedasticity cannot be rejected at 1 % significance. The LM autocorrelation test indicates that the null hypothesis about the absence of autocorrelation cannot be rejected until lag 12 at 1 % significance, taking into consideration that empirical levels of significance or *p*-values up to lag 12 are higher than 0,01.

Finally, the stability of the error correction model was tested by calculation of inverse roots of AR characteristic polynomial using EViews 9 (Figure 1).



**Figure 1:** Inverse roots of AR characteristic polynomial (EViews 9).

The error correction model with  $r$  cointegrating relations is stable if  $n-r$  roots are equal to one and the remaining roots lie inside the unit circle, where  $n$  is the number of variables and  $r$  is the number of cointegrating relations [21]. The estimated error correction model imposes 1 unit root and the remaining roots have modulus less than one. Since there are two variables, namely  $LD\_SA$  and  $LE\_SA$ , and one cointegrating relation, one unit root shown in Figure 1 points to the stability of estimated model. For detailed explanation of problems of heteroskedasticity, autocorrelation as well as AR roots calculation, see [19] and [21].

## CONCLUSIONS

The exchange rate depreciation could have twofold effect on overall economy according to economic theory and empirical research, and thus the exchange rate management is one of the important economic policy question, especially in case of small open economies such as Croatia, which are highly dependent on foreign sector. The impact of depreciation on external debt in Croatia is examined in this article using Johansen cointegration approach. Trace test and maximum eigenvalue test indicate the existence of one cointegrating relation between nominal effective exchange rate and external debt. The estimated long-run equation points to positive statistically significant effect of nominal exchange rate increase on external debt. Therefore, possible depreciation of Croatian kuna could have overall negative effect on Croatia economy. Despite the Marshall-Lerner Condition which implies positive impact of real exchange rate increase by leading to growth in net exports through competitiveness effect, results of this research are not in favor of implementing depreciation. Moreover, depreciation of Croatian kuna is not recommended for monetary policy authorities and therefore current exchange rate policy is suitable taking into consideration empirical characteristics of Croatian economy, especially current state of public finance in Croatia and highly euroized financial system. Further increase in external indebtedness, taking into account that external debt is mostly denominated in foreign currency, is not only unfavorable from the aspect of Croatian fiscal authorities, but also for Croatian National Bank which has

primary function of maintaining price stability what is related to stability of exchange rate of Croatian kuna to euro. Speaking of managing public debt, fiscal authorities role is important in order to sustain fiscal stability for Croatian potential accession to Euro area. Finally, considering the overall situation including monetary and fiscal aspects, the impact of depreciation has positive effect on increasing of external indebtedness. Moreover, possible depreciation and consequently increase in external indebtedness could impede the fulfilment of Maastricht criteria in Croatia, which could not only prolong adopting euro as national currency, but also postpone efficient public debt management taking into account high euroisation.

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## **RADNE VJEŠTINE INŽENJERA U HRVATSKOJ EKONOMIJI: PERSPEKTIVE POSLODAVACA**

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### **SAŽETAK**

Intervencije i diskusije o vještinama koje nastaju u sklopu inženjerskog obrazovanja plijene pažnju raznih aktera i dionika. U hrvatskom kontekstu, sveukupni proces se uglavnom odvija kroz akademske evaluacije, dok je uključivanje alumniija i poslodavaca kao vanjskih dionika rijetko i uglavnom neistraženo područje. S obzirom na to da su hrvatski poslodavci relativno neinformirani o razinama i strukturama reformiranog obrazovnog sustava, glavni je cilj ovog istraživanja bio utvrditi do koje se mjere njihova očekivanja preklapaju sa suvremenim i uglavnom prihvaćenim setovima inženjerskih vještina.

Pregledom dostupne literature, identificirano je 36 vještina koje, putem upitnika dane na ispunjavanje hrvatskim poslodavcima, što je rezultiralo s 418 ispunjenih anketa. Rezultati pokazuju kako poslodavci visoko cijene svaku od ispitanih vještina a posebice one prenosive, vezane uz profesionalnost i radnu etiku, što prikazuje njihovu orijentaciju na funkcionalnost i poslovnu primjenjivost istih. Analiza aritmetičkih sredina pokazuje statistički značajne razlike ovisne o spolu ispitanika, pri čemu žene jasnije zauzimaju teoretizirane dimenzije od muškaraca, što bi moglo naznačiti njihovo razumijevanje vještina, a posebice onih prenosivih, na holističkiji način od muških poslodavaca.

Kako bi se jasnije oslikala latentna struktura istraživanih vještina provedena je eksploratorna faktorska analiza koja je rezultirala u 8 jasnih dimenzija te prikazala „vještine zapošljivosti“ u hrvatskom kontekstu.

### **KLJUČNE RIJEČI**

inženjerstvo, vještine, ishodi učenja, poslodavci

## **POVEZANOST VITKOG I ZELENOG MENADŽMENTA U HRVATSKIM PROIZVODNIM PODUZEĆIMA**

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### **SAŽETAK**

Cilj ovog rada je istražiti vezu između vitkog i zelenog menadžmenta, razloge njihove implementacije, njihov učinak tijekom čitavog životnog ciklusa, kao i trenutnog stanja korištenja vitkih alata, ekonomskih i okolišnih pokazatelja u kontekstu hrvatskih proizvodnih poduzeća. U ovom istraživanju su korišteni polustrukturirani intervjui. Kao rezultat, definirana je učestalost ekonomskih i okolišnih pokazatelja uspješnosti te vitkih alata u hrvatskim poduzećima, kao i razlozi za implementaciju vitkog menadžmenta. Osim toga, došlo se do razumijevanja korištenja LCA metode i okolišnih standarda, a istražena je i integracija vitkog i zelenog menadžmenta u hrvatskim poduzećima. Nadalje, rezultati su uspoređeni s sličnom studijom izrađenom u Velikoj Britaniji. Konačno, može se zaključiti da integracija vitkog i zelenog menadžmenta još nije dovoljno prisutna u proizvodnim poduzećima, iako postoje slučajevi u kojima su ta dva pristupa integrirana, prvenstveno u procesnoj i prehrambenoj industriji. Iz tih razloga u integraciji ova dva pristupa leži veliki potencijal.

### **KLJUČNE RIJEČI**

vitki menadžment, zeleni menadžment, životni vijek proizvoda, upravljanje proizvodnjom, upravljanje okolišem, ISO 14001

## MODEL ZA ISTRAŽIVANJE UČINKA KULTURE RADNE ETIKE NA DINAMIKU PREOBLIKOVANJA U UPRAVLJANJU PROJEKTIMA

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### SAŽETAK

Ova studija nastoji istražiti učinak kulture radne etike na prerade u konstrukcijskim projektima, slijedom pregleda literature, upitnicima i razgovorima s projektnim menadžerima. Glavno pitanje istraživanja je koje mehanizme projektni menadžer može koristiti da uskladi troškove osposobljavanja osoblja, financijske i govorne poticaje, kao i troškove završetka projekta uz veću dobit i manje prerade. Modeliranje i analiza podataka su izvedeni primjenom metodologije sustavnosne dinamike. Rezultati pokazuju kako se, uzimanjem u obzir radne etke, prerade smanjuju s 46 % na 39 %. Dodatno, projekt je završen s 10 % manjim troškovima i 26 % manjom razlikom očekivanja i postignuća. Integriranjem pitanja prerade i kulture radne etike u projektnom menadžmentu proučavano je bar s jednim egzogenim parametrom, dok su kvalitativni parametri pretvarani u kvantitativne parametre primjenom sustava neizrazitog zaključivanja. Jedna od primjena ovog rada je na promjene u menadžerskom pristupu pitanju radne etike i formuliranju strategije velikih projekata menadžerima ljudskih resursa.

### KLJUČNE RIJEČI

radna etika, sustavnosna dinamika, preoblikovanje, upravljanje projektima, građevinarstvo

## STUDENTSKI RAD: ZNAČAJKE I ISHODI NJEGOVE UPORABE U HRVATSKOJ

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### SAŽETAK

Članak se bavi studentskim radom u Hrvatskoj, uzrocima njegove rasprostranjenosti, karakteristikama i pravnoj regulaciji te konačno njegovim utjecajem na sustav visokog obrazovanja i tržište rada. Kroz pregled teorija o radu uz studij, kao osnovni faktor koji određuje motiviranost studenata za studentski rad te različite akademske i profesionalne ishode takve zaposlenosti, izdvojen je fenomen masifikacije visokog obrazovanja (veći broj studenata, njihova veća raznolikost, nezaposlenost mladih i upitna relevantnost diplome). Analiza ovog rada, iako provedena na nesustavnim podacima prikupljenim iz prethodnih istraživanja studentske populacije u Hrvatskoj i EUROSTUDENT međunarodnog istraživanja kvalitete studentskog života, dovela je do zaključka o prisutnosti masifikacije visokog obrazovanja i njezina utjecaja na studentsku zapošljivost, posebice u području društvenih i humanističkih znanosti. Motivacija hrvatskih studenata za studentskim radom proizlazi uglavnom iz želje za poboljšanjem životnog standarda i potrebe za radnim iskustvom, a njihovo prosječno radno opterećenje je niskog do srednjeg intenziteta, uglavnom na poslovima nevezanim za njihove buduće profesije. Osim prikaza prakse upotrebe studentskog rada, članak također daje i pregled njegove zakonske regulacije u Hrvatskoj te primjere njegove zloupotrebe, odnosno negativne implikacije na studente i regularne radnike koje takav rad može proizvesti.

### KLJUČNE RIJEČI

studentski rad, regulacija studentskog rada i njegova zloupotreba, masifikacija visokog obrazovanja, tržište rada, EUROSTUDENT

## **SPONA ETIČKOG VODSTVA, POSLOVNOG UČINKA I NAMJERE PROMJENE: POSREDNIČKO DJELOVANJE ZADOVOLJSTVA POSLOM**

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### **SAŽETAK**

Rad istražuje utjecaj etičnog upravljanja na zadovoljstvo poslom kod zaposlenika, na uspješnost posla i na namjeru promjene posla. Razvijen je konceptualni okvir koji integrira zadovoljstvo poslom kao medijativni element a koji ujedno objašnjava sponu etičnog upravljanja, uspješnosti obavljanja posla i namjere promjene posla. Predloženi je model ispitan na podacima o 196 pakistanskih turističkih poduzeća. Rezultati pokazuju kako etično upravljanje pozitivno utječe na zadovoljstvo poslom kod zaposlenika i na uspješnost posla, a negativno utječe na namjeru promjene posla. Nadalje, zadovoljstvo poslom prenosi učinak etičnog upravljanja na zadovoljstvo poslom kod zaposlenika i na namjeru promjene posla. Rezultati upućuju na to da pokazivanje etičnosti upravljanja menadžera na radnom mjestu povećava vjerojatnost da su zaposlenici zadovoljni poslom i povećava njihovu uspješnost na poslu, dok smanjuje njihove namjere napuštanja radnog mjesta. Ovo istraživanje pokazuje kako, u pakistanskom turističkom sektoru, etično upravljanje ima ključnu ulogu u postizanju poslovnih ciljeva. Daljnja bi istraživanja mogla analizirati spomenutu sponu u različitim sektorima i u različitim kulturama, također razmatrajući druge pokazatelje individualne uspješnosti. Originalnost ovog rada je u teoretiziranju i empirijskoj provjeri mehanizama koji doprinose zadovoljstvu poslom te u provjeri veza između etičnog upravljanja, poslovne uspješnosti i namjere promjene posla u kontekstu radnih mjesta.

### **KLJUČNE RIJEČI**

etičko vodstvo, poslovni učinak, namjera promjene posla, zadovoljstvo poslom

## **PODACI O GRAĐANIMA ZA DRUŠTVENU DOBROBIT U KOMPLEKSNIM SUSTAVIMA**

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### **SAŽETAK**

Kombinacija znatnih količina dostupnih podataka, sofisticiranih algoritama strojnog učenja i obrazovano stanovništvo voljno sudjelovati u baratanju podacima, daje dodatne mogućnosti znanosti o podacima prikupljenima za opće dobro iz mase. U ovom radu predstavljam izvatke iz projekta u kojemu sudjelujem, a koji utječe na različite sfere života i na opće dobro. Kompleksni sustavi su svuda oko nas: od društvenih mreža do transportnih sustava, gradova, ekonomija i financijskih tržišta. Razumijevanje kompleksnih sustava može dovesti do rješenja problema poput gladi, globalnih kriza, siromaštva, klimatskih promjena i održivog razvoja uz prekobrojno stanovništvo. Znatne količine podataka i znanost o podacima omogućuju neviđenu računalnu moć i kolektivnu inteligenciju koju treba iskoristiti za rješavanje temeljnih izazova čovječanstvu, poput siromaštva, zaraza, gladi i izazova razvoja.

### **KLJUČNE RIJEČI**

podaci o građanima, Zenodo, kompleksni sustavi

## **KRIZA NOOSFERE KAO OGRANIČAVAJUĆI FAKTOR U POSTIZANJU TEHNOLOŠKOG SINGULARITETA**

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### **SAŽETAK**

Jedno od najznačajnijih otkrića u povijesti čovječanstva je otkriće načina zapisivanja ljudskog znanja, misli i ideja. 1926. godine, rad nekoliko mislioca poput Eduarda Le Roya, Vladimira Vernadskija i Teliharda de Chardina doveo je do koncepta noosfere, ideje da ljudska kognicija i znanje transformiraju biosferu u misaoni sloj planeta. U današnje vrijeme neki mislioci smatraju općenito kako je internet medij koji oživljava noosferu. Prema hipotezi tehnološke singularnosti Vingea i Kurzweila, noosfera će u budućnosti biti prirodna okolina za razvoj strojne superinteligencije do točke tehnološke singularnosti. U ovom radu pokazujem numeričkim modeliranjem kako je našoj civilizaciji nemoguće dosegnuti tehnološki singularitet u bliskoj budućnosti. Navodim kako se tu točku može postići samo ako će internetski centri podataka biti izrađeni kao računalni strojevi koji su znatno naprednijeg hardvera i utroška snage nego sadašnji. Na kraju, razmatram Noos-računala, ili N-računala, kao hipotetske strojeve usmjerene na upravljanje znanjem a ne samo informacijama, znatno učinkovitije od suvremenih računala po pitanju utroška električne energije. Moguće je da će nas civilizacija utemeljena na N-računalima dovesti do točke tehnološkog singulariteta.

### **KLJUČNE RIJEČI**

noosfera, tehnološki singularitet, točka omega, potrošnja energije, Malthusov model rasta, S-krivulja, N-računalo

## **PREMA IMERZIVNOM PROJEKTIRANJU PROIZVODNIH PROCESA KORIŠTENJEM TEHNIKA VIRTUALNE STVARNOSTI**

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### **SAŽETAK**

Članak daje novi pristup implementaciji virtualne stvarnosti u projektiranju i oblikovanju ručnih procesa i sustava. Prikazana je uporaba hardvera i softvera potrebnog za obavljanje različitih proizvodnih – posebno montažnih – zadataka u virtualnom okruženju, koristeći CAD dijelove kao interaktivne elemente. U vezi CAD dijelova, problem pretvorbe formata opsežno je opisan i riješen pomoću softvera za pretvorbu formata kako bi se prevladala postojeća slaba povezanost podataka između CAD sustava i onih hardvera i softvera virtualne stvarnosti. Dva su primjera radnih procesa izvedena u virtualnom okruženju: osovina-u-provrt i zidne utičnice. U potonjem slučaju, tradicionalni pristup projektiranja zadataka montaže korištenjem sustava unaprijed određenih vremena MTM-2, uspoređen je s modernim pristupom u kojemu se zadatak montaže u potpunosti izvodi unutar virtualnog okruženja. Usporedba obuhvaća raspravu o vremenima izvršavanja zadataka montaže. Dodatno, prezentirane su opće i specifične prednosti i nedostaci koji se pojavljuju pri imerzivnom oblikovanju proizvodnih procesa pomoću virtualne stvarnosti, kao i razmatranja timskog i suradničkog rada čovjek-stroj. Na koncu, predložena je primjena novih tehnologija za prevladavanje glavnih problema koji se pojavljuju prilikom implementacije virtualne stvarnosti, kao što su vremenski zahtjevna definicija scene i složena konverzija podataka CAD softvera.

### **KLJUČNE RIJEČI**

virtualna stvarnost, projektiranje montaže, interakcija čovjek-računalo, istodobno inženjerstvo, MTM

## **PREGLED SUVREMENE DIGITALNE KOMPETENCIJE**

Z. Nyikes

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Budimpešta, Mađarska

### **SAŽETAK**

U skladu s očekivanjima Europske unije, Mađarska je vlada za svoj cilj postavila rast razine digitalnih kompetencija stanovništva, značajnost čega ne može biti propitivana. Mogućnost porasta korisničke razine digitalne kompetencije, kao i ispitivanje ostvarenih rezultata, učinit će osposobljavanje učinkovitijim. Digitalne kompetencije moraju porasti kako bi digitalna dobra bila jednako dostupna svima. Većina radnih mjesta i zanimanja zahtijevaju određenu razinu digitalne pismenosti, tako da i zaposlenici i tvrtke moraju znati koja razina digitalnih vještina jest i bit će tražena od djelatnika.

### **KLJUČNE RIJEČI**

digitalna kompetencija, digitalna pismenost, digitalne vještine, svijest o sigurnosti, industrija 4.0

## **KOMPENZACIJA MANJKA DIGITALNE KOMPETENCIJE POMOĆU ERGONOMSKIH SOFTVERSKIH ALATA**

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### **SAŽETAK**

U suvremenom digitalnom svijetu, dnevno treba procesirati veliku količinu informacija. Naša sigurnost ovisi o njihovom brzom i točnom procesiranju. Procesiranje informacija u slikovnom obliku brže je od procesiranja informacija u tekstualnom obliku. Razina vještina informatičkih tehnologija za procesiranje informacija u slikovnom obliku može na taj način biti manja pa je odgovarajući sustav dostupan većem dijelu društva. Jedno pristup leži u uporabi informacijsko-komunikacijskih alata dostupnih ljudima slabijeg vida, ljudima s poteškoćama u učenju, ljudima koji ne govore, starijima, kao i djeci koja još ne znaju čitati. U ovom radu nastojim prikazati razliku u procesiranju informacija u slikovnom i tekstualnom obliku na temelju jednostavnog upitnika. Preporučam korištenje softvera za ergonomske kompenziranje manjka digitalnih kompetencija.

### **KLJUČNE RIJEČI**

svijest o sigurnosti, digitalna kompetencija, ergonomske softver

## **RAZVOJ AUTONOMNE ANTROPOMORFNE MOBILNE ROBOTSKE PLATFORME S KOTAČIMA**

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### **SAŽETAK**

Rad prikazuje kontrolu gibanja inteligentne, autonomne, antropomorfne robotske platforme s kotačima u nestrukturiranoj okolini. Predložena je neizrazita kontrola gibanja takve platforme. Izlazi iz neizrazitog kontrolera su razlika kutnih brzina lijevog i desnog kotača autonomne, antropomorfne robotske platforme te brzina robota. Rezultati simulacije pokazuju učinkovitost i validiranost ponašanja kojim se izbjegavaju prepreke u nestrukturiranoj okolini te kontrole iznosa i smjera brzine autonomne, antropomorfne mobilne robotske platforme s predloženom strategijom neizrazite kontrole. Predloženo je bežična, daljinska kontrola gibanja autonomne, antropomorfne mobilne platforme u nestrukturiranoj okolini.

### **KLJUČNE RIJEČI**

autonomna i antropomorfna robotska platforma s kotačima, nestrukturirana okolina s preprekama, strategija neizrazite kontrole, bežična i daljinska kontrola pomoću senzora

## RAČUNALNA METODA ZA MJERENJE MOMENTA TROMOSTI BESPILOTNIH LETJELICA POMOĆU UGRAĐENIH SENZORA I BIFILARNOG NJIHALA

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Zagreb, Hrvatska

### SAŽETAK

Identifikacija dinamičkog modela i njegovih parametara jedan je od temeljnih problema u području robotike i modeliranja dinamike sustava. Prilikom proizvoljnog gibanja objekta sa šest stupnjeva slobode, kao za slučaj bespilotnih letjelica, ključni fizički parametri su masa i momenti tromosti. Masa i geometrija geometrija/topologija takvog sustava može se se jednostavno odrediti/izmjeriti, međutim prilikom utvrđivanja tenzora inercije javljaju se poteškoće budući da veličina nije mjerljiva statičkim testovima. U ovom radu predstavlja se jednostavna i učinkovita metoda za "on-line" procjenu inercije krutog tijela temeljem njihala i senzorskog sustava letjelice. Mjerni subjekt (tj. bespilotna letjelica) ovješena je pomoću dvije tanke paralelne žice na način da se formira bifilarno torzijsko njihalo oko okomite osi. Upotrebom senzora ugrađenih iz upravljačku jedinicu letjelice, oscilacije se bilježe i obrađuju u svrhu uklanjanja trenda i šuma signala koji se koriste u završnoj fazi procjene momenta tromosti. Predloženi algoritam identifikacije provjerava se eksperimentalno za dva slučaja ovješanih objekata (kutija i puna konfiguracija letjelice) na koje je postavljena upravljačka jedinica.

### KLJUČNE RIJEČI

bespilotne letjelice, računalno određivanje momenta tromosti, bifilarno njihalo, inercijalni senzori

## **UTJECAJ TRAJEKTORIJE CESTOVNIH TRANSPORTNIH VOZILA NA SIGURNOST PRIJEVOZA TERETA**

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### **SAŽETAK**

Rad nastoji istaknuti opće norme djelovanja prijevoznika tereta, s naglaskom na pitanja sigurnosti. Već je ranije uočeno kako razina svjesnosti o pitanjima sigurnosti kod cestovnih prijevoznika u znatnoj mjeri ovisi o sposobnostima uprave. To upućuje na faktor rizika povezan s veličinom i vrijednosti prevoženog tereta. Na određenoj razini razvoja putanje cestovnog transportera, kako većina istraživanja pokazuje, dolazi do znatnog porasta svjesnosti o pitanjima sigurnosti, kojima je porijeklo u raspoznavanju tih problema od strane uprave velikih poduzeća. Rezultati ovih istraživanja u značajnoj su mjeri slični različitim, utemeljenim znanstvenim teorijama kojima je verificirana hipoteza da je glavna prepreka u razvoju poduzeća kombinacija nedostatnih sposobnosti uprave i otpor adaptaciji i promjeni.

### **KLJUČNE RIJEČI**

transport, svijest o sigurnosti, sposobnost upravljanja

## O RAZVOJU INTELIGENTNOG ŽELJEZNIČKOG INFORMACIJSKOG I SIGURNOSNOG SUSTAVA: PREGLED AKTUALNIH ISTRAŽIVANJA

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### SAŽETAK

Rad je fokusiran na istraživanje i razvoj planiranja za inovativne željezničke sustave. Specifični cilj istraživanja definiran je unutar okvira velikog projekta inteligentnog željezničkog sustava Mađarske. Teorijsko istraživanje na sveučilištu kombinirano je s iskustvom prikupljenim u Mađarskim državnim željeznicama. U istraživanju je inteligentni željeznički sustav razmatran uz polazište u plodonosnoj suradnji između akademskih i industrijskih partnera, kako bi se s jedne strane promovirala primjena i integriranje mogućnosti dobivenih kao rezultat istraživanja, a s druge strane uvele inovativne komponente u željeznički sustav. Uz takve postavke, ovaj rad razmatra plan istraživanja, preliminarne i dugoročne rezultate, te kombinira ciljeve i iskustvo kako bi se razvio novi pogled na ovo, izrazito aktualno i izazovno područje istraživanja.

### KLJUČNE RIJEČI

željeznica, istraživanje i razvoj, inteligentni sustavi, kritična infrastruktura, sigurnost

## **ANALIZA DUGOROČNOG UČINKA DEPRECIJACIJE NA INOZEMNI DUG U HRVATSKOJ**

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### **SAŽETAK**

Utjecaj promjene tečaja u malim otvorenim gospodarstvima desetljećima je predmet ekonomskih istraživanja. Prema ekonomskoj teoriji i relevantnim istraživanjima, deprecijacija može imati pozitivan utjecaj na gospodarstvo putem povećanja izvoza i negativan učinak kroz smanjenje osobne potrošnje. Cilj ovog rada je procijeniti utjecaj deprecijacije tečaja na inozemni dug u Hrvatskoj u dugom roku. Dugoročni učinak deprecijacije na inozemni dug u Hrvatskoj procijenjen je primjenom Johansenovog kointegracijskog pristupa. Rezultati upućuju na postojanje jedne kointegracijske relacije. Dugoročni utjecaj deprecijacije tečaja na inozemni dug u Hrvatskoj statistički je značajan i pozitivan, što je u skladu s prethodnim istraživanjima i ekonomskom teorijom. Provedena analiza ukazuje na mogući negativni utjecaj deprecijacije na hrvatsko gospodarstvo kroz povećanje vanjske zaduženosti, što bi posljedično moglo smanjiti bogatstvo svih sektora zaduženih u stranoj valuti. Budući da je Hrvatska visoko eurizirano maleno otvoreno gospodarstvo s visokom inozemnom zaduženošću u stranoj valuti, ovo istraživanje pruža zanimljive rezultate za nositelje monetarne i fiskalne politike u Hrvatskoj. Prema tome, kao rezultat provedene empirijske analize, deprecijacija tečaja u Hrvatskoj nije preporučena kao instrument povećanja izvozne konkurentnosti zbog trenutne visoke vanjske zaduženosti u stranoj valuti.

### **KLJUČNE RIJEČI**

deprecijacija deviznog tečaja, inozemni dug, kointegracijska analiza, model korekcije pogreške, jednadžba dugog roka





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