DR.SC.-01 REQUEST FOR APPROVAL OF THE DISSERTATION TOPIC[1]

GENERAL INFORMATION AND PERSONAL CONTACT INFORMATION OF THE DOCTORAL CANDIDATE

First and last name, and title of the doctoral candidate:	Vladimir Smojver, mag. ing. mech.		
Provider of the study programme:	University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture		
Name of the study programme:	Mechanical Engineering, Naval Architecture, Aeronautical Engineering, Metallurgical Engineering		
Scientist ID of the doctoral candidate:	35003092		
Approval of topic for acquiring a PhD *(please fill in appropriate box)*:	☒ within programme-based doctoral study	☐ on the basis of scientific achievement	☐ Dual doctorate (Cotutelle de these)
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CURRICULUM VITAE OF THE DOCTORAL CANDIDATE

Education *(in chronological order, with most recent first)*:	1. **University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture,** *Mechanical Engineering – Engineering Design*, Graduate, Croatia 2. **University of Zagreb, Faculty of mechanical engineering and naval architecture,** *Mechanical Engineering – Engineering Design*, Undergraduate, Croatia
Work experience *(in chronological order, with most recent first)*:	01.02.2015, Expert Associate The Vehicle Center of Croatia
Bibliography and active participation in conferences:	1. Vladimir Smojver The Evolution of Technical Innovation in Complex Engineering Systems *//FAMENA PhD 2015 Workshop* Zagreb, Croatia, 2015

TITLE OF THE PROPOSED TOPIC

Croatian:	Model evolucije inovacija u razvoju tehničkih sustava
English:	A Model of Innovation Evolution in the Development of Technical Systems

[1] Please name file as: DR.SC.-01 – Last name and first name of Doctoral Candidate.doc
Please send the filled -out form DR.SC.-01, in electronic and written format, and signed, to the appropriate Registrar's Office.

Title in the language of the dissertation (if it is not Croatian or English)	
Area/field/branch (if the doctoral study is performed in a branch)**:**	Technical Sciences/Mechanical Engineering

PROPOSED OR POTENTIAL MENTOR(S)

(name the second mentor in case of interdisciplinary research or if there is another reason for more than one mentor)

	First name and last name, and title:	**Institution, country:**	**E-mail:**
First mentor:	Mario Štorga, Ph.D., Associate Professor	Faculty of Mechanical Engineering and Naval Architecture	mario.storga@fsb.hr
Second mentor:			

MENTOR'S COMPETENCES – list of up to five relevant works published in the last five years

First mentor:	Stanković Tino, Štorga Mario, Shea Kristina, Marjanović Dorian: "**Formal Modelling of Technical Processes and Technical Process Synthesis**", Taylor & Francis UK: Journal of Engineering Design, Volume 24 Issue 3, 2013, DOI: 10.1080/09544828.2012.722193 Pavković Neven, Štorga Mario, Bojčetić Nenad, Marjanović Dorian: **"Facilitating Design Communication Through Engineering Information Traceability"**, Cambridge University Press: Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 27, 2013, p. 91–105, DOI: 10.1017/S0890060413000012 Štorga Mario, Mostashari Ali, Stanković Tino: "**Visualisation of the Organisation Knowledge Structure Evolution**", Journal of Knowledge Management, Emerald Journals, Vol. 17 Issue: 5, 2013 Cash Philip, Stanković Tino, Štorga Mario: "**Using Visual Information Analysis to Explore Complex Patterns in the Activity of Designers**", Design Studies Vol. 35, Issue 1, 2014, DOI:10.1016/j.destud.2013.06.001 Cash Phil, Štorga Mario: "**Multifaceted Assessment of Ideation: Using Networks to Link Ideation and Design Activity**", Taylor & Francis UK: Journal of Engineering Design, DOI: 10.1080/09544828.2015.1070813 (*in press*)
Second mentor:	

TOPIC OUTLINE

Summary in Croatian *(no more than 1000 characters with spaces):*	Razvoj novih tehnologija je jedan od glavnih ciljeva današnje znanosti i industrijskog razvoja. Kako bi stekle dominantan i povoljan položaj na tržištu, tvrtke koje posluju u kompetitivnom globalnom okruženju pokušavaju unaprijediti svoje razvojne procese, razviti nove proizvode ili ponuditi nove usluge na tržištu temeljeno na unaprijeđenim ili novim tehnologijama. Određivanje smjera razvoja tehnologije se u industriji može koristiti za potporu strateškom i dugoročnom planiranju razvoja proizvoda, procesa i usluga. Kod proučavanja razvoja tehničkih inovacija ključan je pojam „evolucija" koji podrazumijeva unapređenje performansi tehnologije kroz vrijeme. Literatura opisuje dva načina evolucije tehnologije: kontinuirani i diskontinuirani. Znanstveni doprinos ovog rada se očituje razvojem unaprijeđenog modela za kvantificiranje dinamike evolucije tehničkih inovacija i njihoveg potencijala za implementaciju u komercijalno spremnu tehnologiju.
Summary in English *(no more than 1000 characters with spaces):*	The development of new technologies is one of the main objectives of today's scientific and industrial development. Companies operating in a competitive global environment are trying to improve their development processes, develop new products or to offer new services to the market based on improved or new technologies. Determining the direction of technology development can be used in the industry to support strategic and long-term planning of the development of products, processes and services. When studying the development of technical innovations, a key term is an evolution that involves the improving performance of technology through time. The literature differentiates between two models that describe the evolution of technology: continuous and

	discontinuous. The scientific contribution of this work would be in an improved model for the quantification of the dynamics of the evolution of technical innovations and their potential for implementation in a commercially ready technology.

Introduction and overview of research conducted hitherto *(suggested length: 7000 characters with spaces)*

The development of new technologies is one of the main objectives of today's scientific and industrial development. To attain a dominant and advantageous position in the market, companies operating in a competitive global environment are trying to improve their development processes, develop new products or to offer new services to the market based on improved or new technologies. Accordingly, current research trends focused on emerging technologies, and their development based on technical innovations, represent an increasingly important part of research and practical efforts in both academia and the industry [1]. Determining the direction of technology development is a method used in the industry to support strategic and long-term planning of the development of products, processes, and services. The purpose of defining the direction of technology development is gaining a structured understanding and description of the relationship between technical innovations, their implementation in physical systems and services and market development that are based on it over time. Although most of the existing approaches used for this purpose are qualitative in nature, researchers are trying to develop quantitative methods to support the determination of the direction of the development of future technologies. Currently, there is no method that can successfully combine qualitative and quantitative approaches in an appropriate manner [2]**.** With the increasing of the complexity of the technical problems that companies face and the consequent rise in the cost of innovation, there is a growing need for companies to cooperate in the creation of innovations. Although development of new products is still predominantly carried out within a single company (in-house), there is a rise in development activities supported by a search, recognition and a transfer of ideas from external sources and collaboration among companies [3]. Companies are increasingly creating innovation by mutual cooperation and in cooperation with customers and suppliers, with the aim of creating new opportunities for the implementation of a technology and its positioning in the market. This trend, driven by social networking for innovation and cloud, mobile and collaborative information technology allows the expansion of a new paradigm in all sectors of public and private action (mechanical engineering, aviation, energy, transport, construction, services, health, education, public administration and defense sector, etc.) [4]. Organizations that operate in highly competitive surroundings, have a need for timely knowledge of emerging technologies [5] in order to timely plan the improvement of production and other processes, and the introduction of new products or services into the market. Research on the conditions and manner of the emergence of new technologies, and the study of the dynamics of their development, are important in theoretical as well as practical terms. The purpose of predicting the directions of technology development is to minimize or eliminate surprises by having knowledge of all the possible outcomes of technical development. Since there is a realization that the traditional models of forecasting the development of technologies, such as Moore's Law [6] or Kryders law, have been proved inaccurate, there is a need for new models that would enable an improvement of insight into the directions for technology development [2].

A key term, when studying the development of technology, is the "evolution" of technology that describes an improving performance of technology over time [1]. The literature describes two models of the evolution of technologies: continuous and discontinuous [2]**.** Researchers who advocate a model of continuous and incremental evolution of technology claim that this process is constantly in a state of recombination and synthesis based on elements of existing technology, and argue that improvement of the performance of technology in these activities are a result of changes in perception, values, culture, organizational structure, resources and core competencies of the people who work in development as well as society as a whole. For them, innovation is a social process based on the accumulation of small improvements, and not on the significant contributions of brilliant individuals. Researchers who advocate a model of the discontinuous evolution of technology claim technology improves through periods of incremental improvements that are dotted with discontinuous shifts. They claim that the products and services that are based on a completely new and innovative technology create significant progress and become the dominant technical innovation resulting in a discontinuous shift. When examining the methods themselves, we notice a fundamental division between qualitative and quantitative methods. A notable qualitative method is the Technology Roadmap Method (TRM) [7], a method in which a plan is created that connects the short-term and long-term development goals with technological solutions that enable the realization of these goals. This method can be applied to planning an incremental evolution of new products, processes, or technologies. Furthermore, this method visually displays connections between markets, products, and technologies over time. Creating a TRM has three main advantages: it helps with defining needs and technologies that can meet those needs, provides a mechanism for predicting technological development and presents a methodology that helps in the planning and coordination of technology development. Other qualitative methods are predominantly based on the bibliography method, specifically the analysis of written documents (such as scientific articles, newsletters, patents, etc.) [8].

Of the existing quantitative methods, undoubtedly the most famous one is Moore's Law [9], which states that the amount of transistors per square inch on an integrated circuit doubles every year. A law similar to the one Moor proposed is Kryder's law that describes the increase of hard drive capacity [10]. Both of these methods are quantitative methods and are derived from the current development of the technology from a particular area and can only be applied in the short-term. Modern quantitative methods mostly use results obtained by qualitative methods as a starting point for research. The majority of methods use data collected from patents, which are formal records of technology innovation. Other noteworthy quantitative methods mentioned in literature are the logistic model [11] which describes the lifespan of technology with an S-curve and Gompertz [2] model which is a supplement to the logistic model and describes the stages of the evolution of technology. Gupta model [12] describes the discontinuous nature of the evolution of technology while the SAW (step and wait) model [2] describes the evolution of technology as an amalgamation of two sub-models,

one of which describes the stagnation of technology and other describes the development of technology [2]. Another approach often mentioned in the literature is based on the study of various technological configurations using combinatorics [13]. In this approach technology development is viewed as a biological process in which different technologies are combined analogous to the joining of DNA [6] and is modeled by the use of statistical, combinatorial [11] and regression models that simulate the development of technology [14]. The challenge in choosing research methods is a great level of the variety of previously applied methods for predicting the development of technology, making it difficult to combine the existing models. One solution to this problem is to try to normalize the existing methods in a way that their results become comparable.

Objective and hypotheses of research[2] *(suggested length: 700 characters with spaces)*

The aim of this research is to develop a model of the evolution of technical innovations in a contemporary socio - technical context. An improved model to quantify the dynamics of evolution of technical innovation and implementation of technology is to be used in simulations of potential future directions of the development of technology to reduce the uncertainty of decision-making in development projects.
The proposed research will verify the hypothesis that, based on the existing records about technical innovations evolution, it is possible to model the dynamics of the technical innovations development and gain insights into the potential future directions of technology development.

Material, participants, methodology and plan of research *(suggested length: 6500 characters with spaces)*

Research in the field of technology development forecasting involves the formulation of models and theories about phenomena in the environment, as well as the creation and validation of knowledge, methods and tools based on these models and theories with the aim of improving the process of predicting the outcome of the development of technical systems and technologies. The current trend of research combines qualitative and quantitative methods and synergises these two approaches in a combined model that would meet the goal of research. In general, when defining the methodology of research in this area, it is necessary to take into account the fact that the nature of research of socio-technical phenomena is heuristic. The research methodology to be used during the making of this dissertation consists of preliminary research, modeling, data gathering, analysis and validation of the research results. The introduction of elements of the general methodology of research in the science of design [15] defined the research methodology, which consists of the following steps:

1) Preliminary research – The beginning of research requires a review of existing scientific and professional literature in the research area. Based on the literature review, an initial description of the current situation will be established, as well as a description of the desired results, with the aim of defining the basic assumptions of the study. For the purpose of a detailed description of the current situation and guidance for further research, empirical research will be conducted in the form of observations and analysis of the existing development of technical innovations. As a result of this step, the objectives of the research are defined (under Research goals). Also, the main research problems, questions, and hypotheses are identified. Moreover, the relevant disciplines and areas that need to be included in a literature review and existing approaches are also defined.

2) Modeling **-** Based on the review and understanding of existing knowledge related to the problem, this step aims to propose new methods and models to predict the dynamics of technology development. The development of models and methods involves the inclusion of the basic theoretical principles of socio-technical systems, the development of technical systems, management of intellectual capital and the available empirical data. During this step, the main descriptive elements of intellectual property (patent) will be identified, which can be used to model the development of technological innovation, and the impact of the development of technical innovations on technology development will also be explored. Moreover, opportunities for improvement of existing models to predict the development of technologies and their applicability to the use of data obtained from patents will also be examined. Finally, rules and influential patterns discovered in the research so far will be identified and their applicability in the development of new models will be analyzed. After that, the identification of impacts between individual indicators and the development of qualitative and mathematical a priori models will follow.

3) Data gathering – initially, it is necessary to conduct a detailed patent analysis and an analysis of the history of the development of technical innovations in a particular area. Furthermore, attention should turn to other potential sources of information such as scientific journals and white papers and their applicability to predict the development of technology should be assessed. Finally, we should not neglect the so-called expert knowledge data collection methods that gather data from experts in a certain area, which is the basis of the Delphi method.

4) Data Analysis - One or more methods for data analysis will be applied to the data collected. The assumption is that the data samples will be very large, therefore data analysis methods that fall into the group of machine learning, such as neural networks, classification or regression will be considered. The data will also be modeled as a graph that will then be visualized and analyzed. An analysis of changes in the value of data over time to define trends during the development of technical innovations and technology will also be conducted.

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[2] The sequence of listing the objective and hypotheses depends on the area of research.

5) Evaluation - The results of the research in theoretical and practical terms will be confirmed in the final step, and so will the accomplishment of the targeted theoretical and practical scientific contributions. By evaluating the research, research results will be compared with the research goals and the advantages and disadvantages of the methods applied will be pointed out. The outcome of this phase will include proposals for necessary improvements and implementation guidance for forecasting real processes of technology development. Based on the conclusions and findings of the final phase of research, guidelines for future research may be pointed out. Given that the theme of research is modeling the evolution of technical innovations, verifications of the model is only possible by comparing predicted outcomes with the actual outcomes which, is hardly feasible as part of this dissertation because of time constraints. One solution to this problem is the application of the method of backtracking.

Expected scientific contribution of proposed research *(suggested length: 500 characters with spaces)*

The expected contribution of the proposed research, as part of this dissertation, is manifested through:
1) The development of a model for quantifying the dynamics of evolution of technical innovation and the implementation of technology.
2) The development of tools for simulating the potential future directions of the development of technology and will be used for decision-making in development projects.

List of literature cited *(no more than 30 references)*

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Total cost estimate of proposed research *(in kuna)*

75000

Proposed sources of funding for research

Type of funding	Title of project	Project leader	Signature
National funding			
International funding			
Other types of projects			
Self funding	All expenses covered CVH d.d.		
Session of the Ethics Committee at which consent was given to the research proposal[3]			

Agreement of the mentor and the doctoral candidate to request for topic approval

I declare under responsibility that I agree with the topic whose approval is requested.

Signature

(first and last name of first proposed mentor)

Signature

[3] Fill out only if needed

(first and last name of second proposed mentor)

Signature

(first and last name of doctoral candidate)

STATEMENT

I declare under responsibility that I have not submitted a request for approval of an identical dissertation topic at any other university[4].

Zagreb, (date)

Signature

(first and last name of doctoral candidate)

Official stamp here

[4] Not required in case of dual doctorate (*Cotutelle de these*)