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A Meta Research on Engineering Design Research

The Case of New Tools and Their Implementation

Supervisor:
Dr. Marco Cantamessa
Professor DIGEP

Candidate:
Muhammad Ahmed Rana
Student ID: S277275

ABSTRACT

Design research is rather a young realm but has progressed due to generally being used in different disciplines with different methods and theories and expansion in its domain with time. It could be referred to as the process that designers employ to better understand the underlying and often hidden aspirations, requirements, and difficulties of end users, also known as the target audience. Machine learning, big data, and Internet of Things, among other game-changing technologies, have resulted in a massive rise in data, and hence it's a matter of interest to take an empirical dig on design research to find out how this field has evolved so far because it is still unclear how to analyze the syntax of the design research in terms of approaches, methods and tools used.

The objective of this thesis is to give an empirical perspective by creating a database of categorized (based on a previous study by Prof. Cantamessa in 2003 on ICED (1997&1999) research papers from the proceedings of ICED (2019&2017) which is one of the most recognized in this domain. The approach includes thorough reading of all the research papers using different techniques by more than one person and code them into five predefined categories with mutual consensus. Based on this dataset an illustrative statistic is developed to compare all four categories. The findings of this thesis can become a pilot to set standards and directions for the community involved.

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Finally, I express my profound gratitude towards my parents Mr. Rana Maqbool Ahmed Javed & Mrs. Azra Javed who have supported me through thick and thin. I specially dedicate this piece of work to them.

Muhammad Ahmed Rana

Turin Italy, March 30

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LIST OF ACRONYMS

ICED: International Conference on Engineering Design

EX: Experimental

NT: New Tools

ALG: Algeria,

BEL: Belgium,

CAN: Canada,

COL: Colombia,

DEN: Denmark,

FRA: France,

GRE: Greece,

IND: India,

ISR: Israel,

JAP: Japan,

MAL: Malaysia,

NETH: Netherlands,

NZ: New Zealand,

RUS: Russia,

SK: South Korea,

SPA: Spain,

SWI: Switzerland,

TUR: Turkey,

USA: United States

Oth: Others

EMP: Empirical

IS: Implementation Studies

AUS: Australia,

BRA: Brazil,

CHI: China,

CRO: Croatia,

FIN: Finland,

GER: Germany,

HK: Hong Kong,

IRL: Ireland,

IT: Italy,

LUX: Luxembourg,

MEX: Mexico,

NOR: Norway,

POR: Portugal,

SIN: Singapore,

SLO: Slovakia,

SWE: Sweden,

TAI: Taiwan,

UK: United Kingdom

1. Introduction:

1.1 Engineering Design Research (History and Evolution):

Engineering design research is a tool for discovering, describing, organizing, rationalizing, and applying design information (Pugh 1990)[1]. Design research attempts to enhance the existing state of design by enhancing our understanding of the phenomena of design in all of its complexity, as well as developing and validating information, methodologies, and tools (Blessing 2002)[2]. Design might be characterized as a field in its own right, irrespective of the different sectors in which it is used, based on the progress made so far (Andreasen 2001)[3]. Rather than rigorously describing empirical principles, design research aims to create new knowledge systems. Design knowledge is intrinsically complex, with sources ranging from formal scientific information to tacit human understanding. Engineering design research has progressed rapidly in recent decades, and as a consequence, it presents a jumbled, if not chaotic, image (Arciszewski 1990; Hundal 1990; Tomiyama 1990).[4] The reason for this is because when information grows, the order of knowledge does not naturally evolve. Nonetheless, science entails a desire for order, which manifests itself not only in the organization of information, but also in the techniques of investigation (Davies 1968)[5]. The prevailing theoretical/methodological paradigms of reasoning imply that research in the natural and formal sciences is often organized. These types of paradigms have yet to be discovered in the field of engineering design.

Bruce Archer and John Chris Jones, both engineers who grew interested in design, were two of the major protagonists in the British design techniques movement. They have been among the planners of the very first conference on design approaches, which took place in London in 1962 at Imperial College. Jones' groundbreaking book Design Methodologies: Roots of Human Futures was initially published in 1970, and it provided a range of methodologies that designers may employ, most of which were derived from other areas. Two factors concerning his approach selection are noteworthy. To begin, he intended to provide designers the ability to work at elevated amounts of systems and community design, including at the tier of goods and components. Second, he wanted to make the designer's approaches explicit, moving away from the prevalent notion that design comes from a black box of inspiration and toward the realization that a well-articulated

methodology may substantially aid the design process. Jones is also known for his criticism of the design methods movement in 1977, when he said that design approaches had grown too inflexible (Bayazit, 2004)[6]. His departure was a crucial factor in the death of "first generation design approaches," as Horst Rittel had previously described them (Bayazit, 2004, p. 21)[7].

Bruce Archer was substantially more nimble than some of his predecessors in defining design as a process that exists between science and art. Tomás Maldonado convinced him to join the faculty of the Hochschule für Gestaltung in Ulm, Germany, in 1960, where he believed Archer would act as a mediator between several groupings of faculty members who had strong views on the nature of design. Archer moved to England in 1962 to direct a research project at the Royal College of Art on medical equipment design. Archer's establishment of the Industrial Design Research Unit at the RCA in the early 1960s was a watershed moment for design research. When the Design Research Unit was renamed the Department of Design Research, it was integrated into the institution's other graduate programs. Archer presented an appendix with a slew of study conducted by students in the Department of Design Research in a seminal 1980 article, Design: Science: Method (Archer, 1981). The studies were noteworthy for their emphasis on specialized objects rather than consumer goods, as well as their rare examination of values, methodology, and other pertinent issues. While the bulk of research focused on particular items, such as medical equipment, devices for physically challenged children, or government command and control consoles, a few were more abstract, such as the creation of analytical modeling tools for use in design. Archer's article also includes a second appendix that comprises research on art and design history, design education, and graphic design undertaken by associated departments (Archer, 1981)[8]. Despite the fact that Archer did not elaborate on why he believed cultural studies were a necessary component of design research, he recognized a connection between the two.

Design methodology, as well as the topic of how to describe design, were important concerns when the Design Research Society (DRS) was created in 1976, with Archer as one of the founding members. Was it a science or something else that used scientific principles? What differentiated design knowledge from other types of knowledge? At DRS conferences, questions about what constituted design knowledge, how design could be defined as a field, and what precisely were designerly modes of knowing persisted, and were continued in Design Studies, the DRS journal created in 1979.

Today, design research is a global interest. Various beginning sites may be chosen to trace its origins, but the design methods movement in the United Kingdom is a good place to start since there is a clear path from there to where many researchers are now. The area of design research, on the other hand, is far bigger than most researchers realize, and it includes a wide range of players, many of whom have little, or no understanding of what others are doing. In reality, the area is made up of a number of different discourse communities or networks, each of which pursues its own goals based on its own set of best practices and measurable outcomes. These groups have a variety of goals and are of various sorts. For some, the goal of research is to develop new goods. Others are interested in learning more about design as a cultural phenomenon. As a result, we must acknowledge that the word "design research" has diverse connotations depending on who uses it. However, one cannot convey the appearance that discourse groups are isolated from one another. Instead, they regularly overlap and, in some cases, merge. Researchers often belong to many groups and travel between them. Journals, websites, and conferences may have their origins in a certain community, but they often draw scholars from beyond that group. Cross-pollination, in reality, is how a study area with several communities grows and delivers discoveries that go beyond the restricted interests of any specific group.

1.2 Science and Engineering:

The study of the natural world via observation and experimentation is generally referred to as science. Physics, chemistry, biology, and earth, space, and environmental sciences are examples of "natural" sciences. Scientists, like engineers, employ a reasoning process called scientific inquiry to solve issues.

Brainstorming, reasoning by analogy, mental models, and visual representations are all used in science research and engineering design. These tools are used by scientists to ask questions about the world around us and to attempt to infer principles that explain the patterns they see. Engineers employ them to change the world in order to meet people's needs and desires.

Science is a field of knowledge that includes the study of the physical and natural worlds. Engineering is the use of knowledge to create, produce, and manage a product or process that solves a problem or meets a need (i.e., a technology). Engineers and scientists have distinct

objectives. Scientists try to explain and describe the natural world. Engineers consider a variety of criteria and restrictions while developing solutions to issues, needs, and desires that benefit people, animals, and/or the environment. In today's world, engineering and science are inextricably linked. Engineering design is informed by scientific understanding, and many scientific breakthroughs would not be conceivable without the technical tools produced by engineers.

'Scientists try to identify the components of existing structures, designers try to shape the components of new structures.' (Alexander, 1964)[9]

'The scientific method is a pattern of problem solving behavior employed in finding out the nature of what exists, whereas the design method is a pattern of behavior employed in inventing things ... which do not yet exist. Science is analytic; design is constructive.' (Gregory, 1966) [10]

'The natural sciences are concerned with how things are ... design on the other hand is concerned with how things ought to be.' (Simon, 1969)[11].

Using scientific inquiry, knowledge is built from the ground up, starting with the physical world and progressing upwards to well-tested ideas, which are then translated into more generalized, abstractions of how the world functions. It is possible to split the resultant construction into three levels, each of which is connected by two bridges.Here on Earth, we discover physical objects of scientific interest, such as grasses and grazing herds on the African savannah, stars and hot gases visible throughout cosmic time, and organized electronic phases that develop within a thousandth of a degree of absolute zero.

On the bridge to the level above, physical things become objects of study through human perception, which is furthered by instruments such as radio telescopes, magnetometers, and binoculars, and which yields results that can be recorded and shared, thereby advancing the frontiers of human understanding. Observations are the means by which information is transferred from the domain of physical objects to the realm of symbols and ideas. Scientists provide specific descriptions of what they see at the next level of information flow.

Concrete descriptions serve as a bridge to the top level of this picture of science, driving the development of theories by first generating ideas about how the universe works, and then by permitting testing of those ideas via an intellectual type of natural selection. Among the winning characteristics of theories as they vie for attention and application are their simplicity, breadth and

precision, as well as their breadth and precision of observational tests—and the degree to which theory and data coincide, of course.

Newtonian mechanics is used as a model for this kind of analysis. Its breadth encompasses each matter, force, and motion, and its accuracy is mathematically perfect in its calculations. Both its practical effectiveness as well as its inadequacy as a final theory may be attributed to the breadth and accuracy of its scope and precision. Despite the fact that Newton's Laws offer exact predictions for movements of any speed, careful observations may show the inadequacies in their predictions. Knowledge thus goes from the bottom to the top in scientific inquiry: Physical systems form tangible descriptions as a result of their observation and investigation. Concrete descriptions help to create scientific hypotheses by making suggestions and then testing those suggestions.

While data moves from matter to mind in scientific investigation, information is transmitted from mind to matter in engineering design. Investigation obtains information using instruments, while design employs information obtained through instruments. When it comes to design, inquiry molds its descriptions to match the physical world, and when it comes to inquiry, design develops its statements to accommodate the physical world

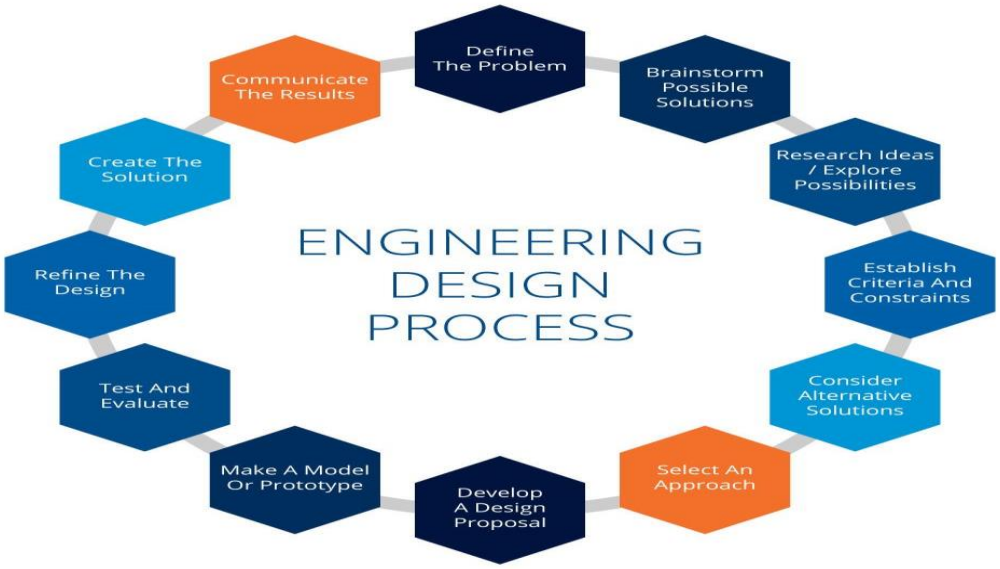
Here, the differences are as tangible as the distinction between an academic laboratory microscope and a milling machine on a manufacturing floor, to name just a few of examples. Even at the higher, more abstract stages of engineering and science, the changes are less tangible, but they are at least as significant. The differences in this case are around designs and theories, which are both intangible but quite distinct creations of the mind.

Scientific theories must be original and accurate; if numerous theories seem convincing, however only one must be incorrect; while engineering theories must be proactive and innovative; if a number of design solutions are successful, success is certain.

Scientists look for theories that can be used over the broadest possible range (for example, the Standard Model can be applied to everything), while engineers look for ideas that are well-suited to specific areas The goal of scientists is to formulate hypotheses that make precise, thus fragile predictions (such as Newton's), but the goal of engineers is to develop systems that have a large margin of safety. The difference between science and engineering is that one failed prediction may

discredit a theory in engineering, regardless how many prior trials it has passed, but in science, one design solution can validate a notion, no issue how many earlier iterations have failed.

1.3 Brief Overview of Engineering Design Process:



https://www.twi-global.com/technical-knowledge/faqs/engineering-design-process

Engineering research is the procedure that engineers use to identify and solve problems. It's been described and mapped in a variety of ways, but there are certain similar characteristics in all of them. Design for engineering: This effective problem-solving strategy is adaptable enough to function in practically any circumstance. At each stage or phase of the process, engineers get valuable knowledge about the issue and alternative solutions.

The creative process of recognizing requirements and then designing a solution to meet those needs is known as engineering design research. Depending on the situation, this answer might be a product, a strategy, a structure, a project, a method, or anything else. The Engineering Method of Creative Problem Solving is the overall technique for completing a successful engineering design. The process of choosing the best feasible action to take in a particular scenario is known as problem solving. The kind of challenges that engineers must tackle differ across and within engineering disciplines. There is no general set of techniques that will suit every situation due to the multiplicity of difficulties. Although not every engineer follows the same phases in their design process. The

engineering design process is a series of steps that engineers follow to find a solution to a problem. Although these steps are not strictly predefined, but some generic steps are defined below.

1.3.1 Identify the issue

What is the issue that must be resolved, Who is the design product for, and why is finding a solution so important, What are the constraints and prerequisites, Regardless matter what is being developed.

1.3.2 Create a list of potential solutions.

Before beginning a design, good designers brainstorm various solutions, compiling a list of as many as feasible. It's preferable to refrain from critiquing the designs and instead allow the ideas to flow freely.

1.3.3 For your Engineering Design Project, Research Ideas / Explore Possibilities

Make use of other people's experiences to expand horizons. Avoiding the pitfalls that others have encountered by investigating previous initiatives. Talking to individuals from different walks of life, such as users or consumers. You could come across some solutions that you hadn't considered before.

1.3.4 Establishing Criteria and Constraints is the fourth step.

After compiling a list of prospective solutions and defined the project's requirements based on your research, the following step is to identify any constraints to your work. This may be accomplished by going through the criteria again and combining your discoveries and thoughts from the previous processes.

1.3.5 Think about other options.

One can choose to investigate other options in order to assess different results and determine the best course of action. For each feasible concept, this will entail repeating some of the preceding procedures.

1.3.6 Pick a strategy

After weighing alternatives, one can be able to decide which technique best matches your needs. Those that do not satisfy your qualifications should be rejected.

1.3.7 Come up with a design proposal

After deciding on a strategy, the following stage is to polish and enhance the solution in order to generate a design proposal. This stage may last the whole duration of the project, as well as after the product has been delivered to clients.

1.3.8 Create a prototype or model

Making a prototype of design concept so it can test how the final product will function. Prototypes are often built of different materials than the final product and are completed to a lower level.

1.4 Why International Conference on Engineering Design?

The International Conference on Engineering Design (ICED) is the hallmark conference of the Design Society, a non-profit organization founded in 2001 on the foundations built by Workshop Design-Konstruktion (WDK) to encourage the advancement of design knowledge in all areas. The ICED conferences began in Rome in 1981 and have been conducted every two years in fifteen nations since, with one additional meeting every two years. Under the aegis of WDK, thirteen conferences were held. The Conference follows the same structure as previous years, including plenary sessions, podium speeches, discussion sessions with concentrated debate, and workshops run by Special Interest Groups of the Design Society. It is a diverse program that gives an exciting chance for scholars and practitioners to learn about the newest breakthroughs in engineering design, as well as substantial networking possibilities.

The goal of the International Conference on Engineering Design is to bring together top academic scientists, researchers, and research scholars from across the world to discuss and share their experiences and research findings on all areas of Engineering Design. It also serves as a leading multidisciplinary forum for scholars, practitioners, and educators to present and debate the most current breakthroughs, trends, and issues in the domains of Engineering Design, as well as practical difficulties and solutions.

Among the reasons that why the proceedings and papers from this conference are selected to take an empirical dig on engineering design and research in this field are mainly the diversity and reputation this conference has in its core. Design research from different sectors are presented by novel scholars, scientists, Researchers, students and industries. Which will help us to fully understand the gaps which has been covered until now in this field which is rather young but has a lot of data information sharing.

The purpose of this study is to contribute to the discussion on the basics of design research by offering preliminary empirical 'cross-sections' of the research community's work. It accomplishes so by examining the papers presented at the International Conference on Engineering Design in 2017 and 2019. (ICED). The choice to analyze the information provided at ICED was made since it is one of the biggest and most comprehensive conferences in the field of design research. Choosing a single conference may result in bias, such as an overrepresentation of European researchers' work and, as a result, of the study topics they choose. In terms of the generality of the findings given in this work, the likelihood of such a bias should be regarded a limiting factor.

In Kuhnian terms, the objective of the paper is to investigate the extent to which design research may be an identifiable research paradigm. (Cantamessa 2003) [12]

A paradigm, according to Kuhn (1996)[13], is a combination of study issues, underlying theory, and research methodologies that become generally accepted within a scientific community in the intervals between scientific revolutions. The paradigm's value lies in the fact that by adhering to it, researchers don't have to 'go back to basics' every time and may build on each other's work, propelling the study topic forward in a quick series of incremental advancements. The process continues until the paradigm's theory and procedures have reached their limitations and it is no longer capable of addressing new challenges. At this stage, the old paradigm is pitted against new competing and' revolutionary' paradigms, each based on a different theory and approach, with the winner being the one that solves the problem the best. In the end, research issues win. From this vantage point, design research may be seen as a relatively new subject that sprang from innovative ideas and suggestions. The degree to which it has progressed into a clear paradigm, or if it is still in a pre-paradigmatic stage, should be investigated.

1.5 New Tools & their Implementation

New tools and their implementation have been by far those categories (defined by Prof Cantamessa) that have progressed the most in term of application in all the aspects of engineering, science, business, environment, education, health. There could be several reasons for this progress which we will discuss in the following sections of analysis and conclusions. But putting it in a perspective that because of the boom in technology, internet accessibility, Artificial Intelligence, the amount of saved data has increased exponentially hence using this data as foundation to make new tools and their implementation became easy in comparison to work previously done into these two categories.

1.6 Problem Definition and Objective of Thesis

As mentioned in the abstract the domain of engineering design research could be considered young as compared to others but is used in different disciplines with different techniques. As it could be seen that this domain is being used in all major aspects of life but still it is unclear how to analyze the syntax of the design research in terms of approaches, methods and tools used because of lack of set standard and rules. So, the objective of this thesis is to find out how this field had evolved so far specially in past two decades because Machine learning, big data, and Internet of Things, among other game-changing technologies, have resulted in a massive rise in data which makes it even more interesting to know are we still able to set some standards in this domain. For this reason, proceedings from a well known highly reputed International Conference on Engineering Design are chosen and all the papers presented in the years 2019 and 2017 are thoroughly read and categorized in to different predefined categories.

1.7 Thesis Outline

The thesis consists of five chapters. The first chapter “Introduction” includes a brief outlook of design research history, evolution with time, engineering design process and some generic steps, why we chose ICED for this meta research, and the category of new tools and implementation studies. Second chapter is dedicated to existing literature review related to the topic of discussion

and theoretical background with an emphasis on Design Research. In the third chapter, methodology & approach for research is defined. Fourth chapter includes the analysis of the data collected using different approaches. Last chapter of the thesis discusses the results of the approach and propose recommendations.

2. Literature Review

Before stating the methodology and implementation part of this thesis, a foundation must be built to prepare the reader to understand the terminologies and concepts associated with design, design research, design research methods and engineering design research.

A design approach is a broad concept that may or may not contain a methodology guide. Some are used to direct the design's overarching purpose. Other methods are used to direct the designer's inclinations.

These are some of the approaches:

Design artifacts are used as an embodied criticism or commentary on a culture's current values, beliefs, and behaviors. Ecological design is a design strategy that emphasizes the consideration of a product's or service's environmental implications over its entire lifespan.

Participatory Design (originally co-operative design, now commonly referred to as co-design) is a method of using collective creativity to design, with the goal of actively involving all stakeholders (e.g., employees, partners, customers, citizens, and end users) in the process to ensure that the end product meets their needs and is usable. Scientific design is a kind of industrial design that is based on scientific understanding.

Science may be utilized to investigate the consequences and requirements of a new or current product in general, as well as to create goods based on scientific knowledge. For example, examinations of filtration performance, mitigation performance,[13] thermal comfort, biodegradability, and flow resistance may be used to develop a scientific design of face masks for COVID-19 mitigation. [14]

Designing or structuring the experience surrounding a product and the service connected with its usage is known as service design. Sociotechnical system design is a philosophy and set of tools for collaboratively designing work arrangements and supporting processes for organizational goals, quality, safety, economics, and customer needs in core work processes, as well as the quality of people's work experiences and societal needs.

Transgenerational design is the process of creating goods and surroundings that are compatible with the physical and sensory limitations that come with age and restrict key daily activities.

User-centered design focuses on the requirements, desires, and limits of the developed artifact's end user.

International competition and technical advancement, along with an unrelenting demand for higher-quality goods and the presence of product liability regulations, have compelled industry to take the following actions:

• To accelerate the adoption of innovative technologies.

• To shorten design timeframes.

• To ensure that designs are done correctly the first time.

• To innovate more regularly and to generate more inventive goods; • To increase product and system dependability.

To address the answers, industry and academia have concentrated their research efforts on methods to automate and steer the design process, or at least portions of it, while simultaneously increasing the process's quality and results. It is widely understood that before a process can be automated, a thorough understanding of how it runs, how it may be improved, and even how it might be optimized, is required. Numerous scholars, most notably Marples (1960) and Hales (1987)[15], have investigated the engineering design process as it is used in certain industries and industrial settings and have offered concise explanations of the engineering design process.

Of course, such research must continue since the context in which engineering design is practiced is, to put it mildly, dynamic.

Additionally, it is necessary to do research on the specific activities involved in the process in order to give both depth and breadth of knowledge. For instance, in recent years, considerable effort has been done to develop computer-based tools to assist engineers and designers during the conceptual phase (Hennessey 1994, Ullman 1995, Scrivener et al 1993)[16]. The majority of these tools are based on descriptive research rather than prescriptive design concepts (Al-Salka et al., 1998)[17].

Given the dynamic nature of the engineering design process hence the need for more specific information of design activity, numerous research methodologies and procedures have been adopted and developed.

It is intended that a close examination of the designer's actions would reveal the cognitive processes that underpin intellectual functions also including cognition, problem solving, and creative thinking.

Thus, within the subject of engineering design research, it is widely understood that a strong research methodology is required that employs reliable research methodologies both individually and in combination integrated into a multi-method strategy Triangulation of findings from several approaches used in one research study or across many other studies is also widely recognized. The design research community relies on rigorous methods for triangulating or comparing data. Individual researchers would be able to duplicate triangulation studies more quickly if there was a globally agreed-upon approach for doing design research. Even if design research literature does not give much information on the nature of such a methodology, the absence of established and repeatable research methodologies and processes to assess suggested theories and concepts of design activity is widely acknowledged (Ehrlenspiel and Dylla 1993)[18]. An experimental triangulation approach developed by the Design Research Group at Glasgow University has been tested on three research projects. To begin with, only concepts were tested, even though this technique may be used to every stage of the design process for an engineering project. Following parts of this article detail the development of the approach and give first test findings. Triangulation of research findings received via diverse approaches and across different research projects may be achieved using the suggested management methodology, according to the outcomes. An effective management tool may then be built on this solid base.

Research in engineering design has often relied on data gleaned from the observation of designers working in a laboratory setting on a specific assignment Since the beginning of the 1980s, the number of 'protocol studies' has continuously increased, but these programs have taken place in isolated clusters (Dorst 1995)[19]. Observation of designers at work is a part of the process. In majority of these investigations, what we would term 'experimental data' is collected in the laboratory.

Many design protocol studies are focused on limiting or balancing the 'variables of the research equation' (Dorst 1995)[20]. Such logical notions do not apply when designers operate "for real."

Experiments such as this one are 'less typical for assessments of how design really takes place in reality', according to Dwarakanath & Wallace (1995)[21]. Acknowledging that a laboratory setting

"usefully reduces the impacts on the design process" helps to strengthen the credibility of their protocol studies and their claim. In September 1994, major researchers in protocol analysis met at Delft University of Technology for the first time (Dorst 1995)[22]. Though they may be based on data obtained in "controlled laboratory contexts," the studies show that there are still several ways to interpret the findings. There have been studies that looked at the participants' words as a more or less accurate representation of what they were thinking. Some people focused on the designers' sketches, while others paid attention to their hand movements.

Because of its scientific foundation, the protocol approach has gained widespread acceptance as a tool for analyzing engineering design activity. Modern field research methods from the social sciences have been recommended to aid in the understanding of how and why design occurs (Wallace and Hales 1989, Kennedy 1997)[23], since engineering is increasingly recognized as primarily a human activity. Ethnographic observation is one example of a social science method that employs ethnography. There are several ways to conduct an ethnographic study, but the goal is to offer a documented account of the group's tacit norms and customs. The goal is to produce a 'thick' or 'rich' account of the observed group's experiences, which interprets their thoughts and feelings (Robson 1993)[24]. It varies from a protocol method in that it observes rather than participates in the action being observed. The researcher has a wide range of options when it comes to observing. As a participant observer, you become a member of the community you are studying. It is common for academics to acquire access to firms and work as designers or alongside designers in order to gain an insider's perspective of their work. Research might become more or less organized when new ideas develop from the data collected (Kennedy 1997)[25]. In the realm of design research (Bucciarelli 1994)[26], a participant ethnographic study of a photovoltaic cell manufacturing company was conducted. For example, it shows the impact of time, money, and resources limits on real-world activity. Moreover, the social environment between designers and management has an impact on how they work.

History is the study and interpretation of past events based on information gleaned from historical documents and narratives. Primary and secondary sources are used by historians to categorize material. There are a variety of primary sources, such as firsthand reports from participants or bystanders, contemporaneous documentation, such as personal notes, memoranda, instruction

manuals, and diaries. Other historians and scholars have written summaries and accounts of the events in question in secondary sources.

For present study, a historical foundation or backdrop is essential.

For example, design advancements brought on by the advent of new technology might be compared to previous advancements.

Some scholars in the field of design have used their personal experiences as designers to explain elements of the discipline. As a result of his own design work, French (1992)[27] presents a model for the process of design. According to Pahl and Beitz (1984)[28], this model is based on identical assumptions. According to Beitz 1994, and Cross 1993[29], design scholars are worried about the lack of adoption of their concepts by practicing designers. Including designers as equal partners in the study increases the likelihood that the research's findings will be adopted because of the shared ownership of the research's findings.

Using a method comparable to participant observation, researchers and designers may collaborate to gain a common understanding of their work. The 'focus group' technique is also a prevalent one. As a group of practitioners/researchers, we are able to build theories and tactics based on our common understanding of the world in which we live.

3. METHODOLOGY

3.1 THE SEGEMENTATION

The ICED research papers cover a broad variety of topics, which makes them difficult to compare, even more so given the unusual criteria utilized at the two events for increasing presenting streams. As a result, a new categorization has been devised, principally based on the study objectives about the design process. Five categories were devised by Prof Cantamessa in 2003 in a research paper.

(i) Empirical research (Emp), in which researchers analyse real-world design processes.
(ii) Experimental research (Exp), in which researchers set up design
experiments in a controlled environment i.e, laboratories.
(iii) Development of new tools and methods (NT) for supporting the design
process or the elements related to it.
(iv) Implementation studies (IS), in which researchers discuss the real-world deployment of innovative design methods and tools.
(v) Other (OTH), which includes papers dedicated to theory and education.

This categorization was formed on the premise that if the design research community is doing different types of research, it must be with the intention of capitalizing on their complimentary nature. As a result, the types of exploration activities have been thought to stimulate the development of a comprehensive life-sized model of plan study in which their common connections should be easily made clear and eventually evaluated.

3.2 THE CLASSIFICATION

The method followed is simple yet tricky at the same time. This process was kicked off by reading all the design research papers published in the International Conference of Design Research (ICED) in the years 2017 and 2019. A set of pilot papers were given to three reviewers who are pursuing their master's degree in Science – Management Engineering specialization (all from three different nationalities) and different specialization backgrounds.

These pilot papers were randomly picked from a sample size of over 750 papers published in both the conferences. The papers were divided equally among them and were asked to read them to get an idea about each paper and categorize them under the 4 categories as mentioned above.

For starters, these papers were read and understood by the reviewers thoroughly point by point to understand the type of research. Different universities specialize in different fields. The brightest of minds from various countries have contributed to the field of automotive, electric, electronic, healthcare, gaming, environment, economy, geography, and a lot more. These types of papers were scrutinized and coded into a data sheet.

3.2.1 THE SUB-CLASSES

Each research falls into each type of paper. The core idea of the students or the professors or the researchers would have been different, but the aim of this meta research was to classify further into sub-classes by commenting and anticipating within the design field to make it understandable and fall well within the idea of this meta research. For example, if a particular design and development paper had individuals involved as a part of their experimentation, they were sub-grouped as experimentation papers.

A few other basic questions under each category are as follows. Each criterion by which the papers are classified is explained below each category along with its legend.

a) **EMPIRICAL STUDIES**

Empirical study: **General Objective : nature of design (2) - specific tools/method (1) - unclear(0)**	**Emp:** **Approach: case study/interviews (qual) (2) - survey (quant) (1) - not clear (0)**	**Emp:** **Analysis unit: individual (3) - project/team (2) - firm/company (1) - unclear (0)**	**Emp:** **Number of cases / sample size / nr of units of analysis**	**Emp:** **Study during the process (1) - after/retrospective (0)**	**Emp:** **Conclusions / implications for practice (education or industry): present (1) - absent (0)**

Empirical research is research that is based on empirical data. It is also a method of learning knowledge by observation or experience, both direct and indirect. The record of one's actual observations or experiences, known as empirical evidence, can be examined numerically or qualitatively. A researcher can answer empirical questions that are clearly defined and answerable with the evidence obtained by quantifying the evidence or making meaning of it in qualitative form. The research design differs depending on the field and the subject being examined.

In most of the papers reviewed, the empirical studies were conducted with participants, volunteers, students, professors, design experts, people involved the specific field where the research is being

done. All these people were being subjected to controlled environments and the study was conducted in the means of either case study/personal interviews (2), surveys (1), focus groups, one-on-one sessions and few other methods to understand and record how each person or subject feels/experiences. The empirical study conducted during the process is marked as 1; 0 if it is done after the retrospective.

Some of these take a few hours and some take days depending upon the product which is being focussed.

b) EXPERIMENTAL STUDIES

Exp: **Objective: nature of design (2) - specific tools/methods (1) - unclear (0)**	**Exp:** **Individual setting (2) - group (1) - with customer/user of the product (0)**	**Exp:** **Conclusions / implications for practice (education or industry): present (1) - absent (0)**

A study that fully adheres to a scientific research plan is known as experimental research. It consists of a hypothesis, a variable that the researcher may alter, and variables that can be measured, calculated, and compared. Most significantly, experimental research is carried out in a controlled setting. The researcher (the author) gathers data, and the findings will either support or refute the hypothesis. This research process is known as hypothesis testing or deductive research.

Data in experimental research must be able to be quantified or measured. The papers are sub-grouped based on three criteria –the objective of the experimental study based on the nature of

design (2) based on parameters that could be area, circumference, density, force, growth (time, weight, volume, length/width), heat, humidity, light intensity, mass, pressure, sound intensity, temperature, time, velocity, volume, or weight; to see the working of a specific tool/method (1). However, the entity should be carefully observed qualitatively, or described using words and photographs. These types of observations help supplement the measurements taken throughout the experiment.

c) NEW TOOL STUDIES

New Tools (Nt): **Software (0) - design method (1) - both (2)**	**Nt:** **If software, is it based on existing software products for the design task (1) - or not (0)**	**Nt:** **If sw, implementation with commercial applications is addressed and possible (1) - or not (0)**	**Nt:** **Reasons for research: no industrial/educational needs (0) - generic reference to needs (1) - specific references to industrial needs (2)**	**Nt:** **addressing implementation of method or tool (1) - or not (0)**

Tools are used in engineering design to complete an action. Engineering tools mainly used in designing projects are software based. Knowledge about design software is the key to this research and the design experts are the main authors in this set of papers from universities knows for their distinguished tool development research.

Here, the papers are divided on five different criteria – if the paper denotes use of s new software as a tool, it is marked as (0), denotation of a design method as a tool is marked as (1) and if both are mentioned in the paper, then a (2) is marked.

If the research uses an existing software [Solidworks, AutoCAD, Creo, Catia, Siemens NX]to carry out a design task, it is marked as (1), else a (0).

Further, the paper is scrutinized for a possibility of an commercial application possibility is addressed (1) or not; if it discusses the implementation method (1) or tool or not (0) is marked accordingly.

The reason for which the research is conducted is very much obligatory to look into since dseigning task is based on the motivation behind the task. The research might be aimed at an industrial need such as design of an automotive component, design of an artificial body part related in the healthcare industry, design method on how to design a particular component or approach on making it comes under a new tool study. Specific needs to such industrial needs are demanded by the design engineer and the customer involved in the big picture. So, this was also taken into account to make sure the paper is being filtered properly.

d) IMPLEMENTATION STUDIES

Implementation: **methods (1) - or tools (0) - or both (2)**	**Impl:** **Awareness of/referring to results from empirical research regarding the topic (1) - or not (0)**	**Impl:** **Objective: Methodology development (3) -generalization of existing (2) -find the way of implementation (1) -discussion (0)**

Implementation is widely considered as the 4th step in the objectives of engineering design. The methods used to make all the engineering work happen is based on how it is being implemented. Right from ancient techniques, implementation has evolved and still reaching unreachable heights and innovation. This bunch of papers has a large proportion discussing the development of implementation methods.

The objective of the study is seen in three ways – if the paper focusses on a development of methodology which is marked with 3, if the paper just states the generalization of existing of the implementation idea is marked 2, if the paper proposes a viable way of implementation is marked as 1 and if the whole paper is a general discussion about the broad study which is marked as 0.

These are also divided based on some criteria – based on the method of implementation (1), the focus on the tools used for implementation (0), or both mentioned above together (2); the awareness or the reference of empirical results derived from the particular topic/research (1) or not (0).

(A Conceptual Framework for Breakthrough Technologies, 2019)

Each sub-group was studied and segmented for the purpose of previous research of papers of the design conference held in 1997 and 1999. Here, it has been modified with some more additions since the many advancements and additions in the field.

Once the reviewers become familiarised with the flow of the papers and the nature of research of each paper, they are properly coded into each category.

After being done with the pilot papers, the sample space of a little over 750 papers was introduced to the reviewers, with around 250 papers per reviewer for both 2017 and 2019 was given to read, review, align and code.

Some of the papers have had industries themselves are the main authors for the purpose of better research. They were also marked exclusively in a separate column.

In the end of categorizing and coding, all papers were marked based on a few common grounds on a scale of 0 to 2. The criteria followed were as follows:

- References to theories: design theories (2), other theories (1), no theories (0)
- Clear description of, or section on methodology /approach /methods used (1), none (0)
- If data collection: Clear description of, or section on research methodology/methods (1), none (0)
- If Data Analysis: Clear description of, or section on research methodology/methods (1), none (0)

A screengrab from the fully coded dataset with an example of a set papers from the lot coded into their respective category along with the author, their university (internal collaboration and cross-country collaboration), their home country, is pinned below for a better understanding of the coding methodology.

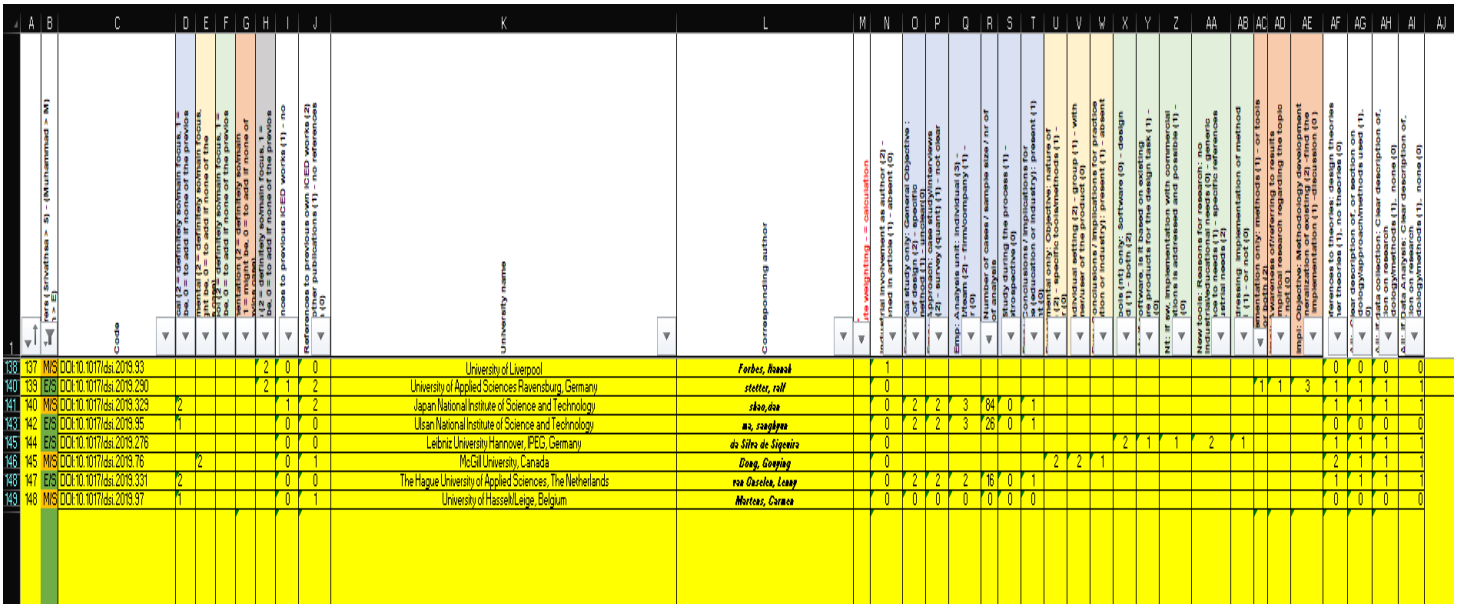


Figure 2.1 – Screenshot of fully coded papers with color codes

The color codes are designed for better understanding. The coding is done from a right-left fashion starting from identifying the paper by its issue number in the conference. The same method was followed sorting the papers of 2017. In this screengrab, a batch where all types of categories visible are shown for better understanding. The paper is read thoroughly and marked if it comes under empirical (blue), experimental

(yellow), implementation (pink) or new tool studies (purple) with (2). In case of a doubt or a confusion if the paper's focus might not be on the main category, it is marked with (1) and (0) if nothing adds up and the customary reason is added so that the sorting error is avoided.

The name of the university, country and the author's name is entered manually. Some papers are authored by the design engineer or person working in an industry [most of the papers mentioned is authored by Daimler AG, some being co-authored by according to industries]. This classification is considered important because industries have a major impact on the design field, since they are the makers of real-life products and expertise research will go a long way in the field of engineering design.

If the paper doesn't denote any category and serves just as a surface level discussion on the design field and their advancements, they will be marked as Others (grey), which in real time is hardly categorised.

There are also other papers which focus on design of circular economy, additive manufacturing, knowledge reuse, human response detection in the futuristic robotic research, agile product development in the electricity sector, sports, home appliances, and many more

4. Analysis

4.1 Types of Research Papers

As noted, before in the "Methodology" section, conference papers were classified into five distinct groups. The categories are denoted by the initials EM for empirical research, EX for experimental studies, NT for new methods and tools, IS for implementation studies, and OTH for additional articles that do not fit into any of the other categories. While some publications belong to a category, nothing can be stated definitively about the categories to which others belong, save for the type to which they are most closely related.

As a result, two labels were employed to indicate the kind of each study paper: "may be" and "definitely." The following table summarizes the distribution of ICED17 and ICED19 articles by kind.

	ICED17			ICED19		
	Might be	Definitely	Total	Might be	Definitely	Total
EM	11	60	71	9	90	99
EX	4	51	55	3	48	51
NT	17	92	109	9	86	95
IS	37	106	143	47	85	132
OTH	8	26	34	13	17	30

Table 1. Distribution of papers by research type and conferences

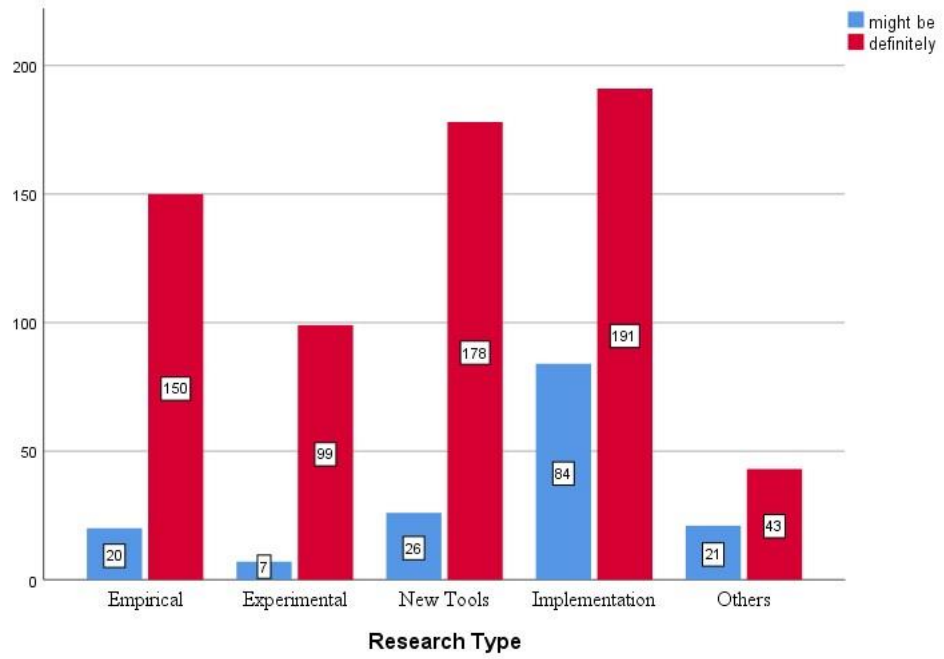
4.2 Dominance of New Tools and Implementation

As can be seen from the data IN Table 1, implementation studies proved to be the most popular study category at both ICED17 and ICED19. The development of new techniques and tools was the second most prevalent research subject in ICED17 papers, and it was the third most prevalent research theme in ICED19 articles. When it comes to ICED17 papers, empirical studies come in third position, whereas they come in second place for ICED19 articles.

When the number of articles that fall into the "definitely" category is taken into consideration, the rankings for ICED17 papers remain same, however the results for ICED19 papers are much different. When only papers that fall into the "definitely" category are considered, the dominating research type at ICED19 shifts as well. The reason for this is that, although the number of papers in

the "might be" categories at ICED17 is not very great, the volume of implementation studies in the "might be" categories in ICED19 is not insignificant. In this case, while considering just papers in the "definitely" category, the ranking for ICED19 articles is completely different.

When the number of implementation studies is compared to the total number of other forms of research presented at both conferences, it becomes clear that the number of implementation studies is much more than the total number of other types of research. Due to their shared characteristics, NT and IS documents may be difficult to discern in certain instances. To begin, as Cross (1993)[30] points out, design science is the attempt to lead the design process in a certain direction by the use of appropriate approaches and tools. Both of these areas are related with design science, and both are concerned with the real world rather than a controlled environment. The bulk of research conducted in real-world settings include both the development of a new approach or tool and its application in a real-world context. The NT Studies were defined as those that featured a brief case study after showing the application of a novel approach or technology. On the other hand, some studies go beyond just proposing a novel technique or instrument and instead focus on its practical implementation. Additionally, it is unknown if the method employed in any of these research was invented from scratch and is being published in its entirety for the first time in the relevant publication, or whether it is an established strategy that is being applied for the first time in the relevant study. Due to these misconceptions, the number of implementation studies classified as "might be" has grown. To arrive at a more precise conclusion on the most often presented form of research paper, the total number of research paper types presented at the two conferences was examined.



Graph 1. Distribution of ICED17 and ICED19 papers in total by research type

As can be observed from the graph when both conferences are considered combined, implementation studies are the most prevalent form of study. The second most often occurring sort of study is the creation of new tools and methodologies, followed by empirical investigations, experimental studies, and other types of articles. The papers that do not have a distinct category (others) account for less than 7% of all articles. These articles are mostly concerned with theory and education.

4.3 Why New tools and Implementation studies are prevailing?

International competition and technical advancement, along with an unrelenting demand for higher-quality goods and the presence of product liability regulations, have compelled scientist, researchers, industry to take the following actions:

• To accelerate the adoption of innovative technologies.

• To shorten design timeframes.

• To ensure that designs are done correctly the first time.

• To innovate more regularly and to generate more inventive goods; • To increase product and system dependability.

All the aforementioned items provide guidance for using data that has previously been gathered, recorded, or existed in any manner. As stated in the abstract of this thesis, it is a necessity of time to conduct empirical research on engineering design when there is a plethora of information available, laying the groundwork for any new tool, implementation studies, policy formulation, and so forth, and occasionally narrowing the gap between research. As a result, an increasing amount of research now fits into these two categories established by Prof. Cantamessa.

In 2008, as the global economic crisis intensified, several businesses from all walks of life began looking for ways to improve their economic status. The endeavor resulted in the adoption of current management techniques such as Six Sigma, Theory of Constraints, Total Quality Management, and Lean Management. Due of its great effectiveness, the last one became the most popular. The purpose of this section is to discuss why newtools and implementation studies became a dominant categories in these times . A short history of the Toyota Production System (TPS) is presented with its three primary instruments: jidoka, just-in-time manufacturing, and "pull-flow production." Additionally, the way businesses that practice Lean Management operate as a direct successor to TPS. Hence it can be looked as paradigm shift in design research after the crisis that more and more research was based on making new tool, methods, instruments, processes, implementation, policies rather than going for experimental studies in which you require a whole new problem statement and hence a controlled environment following the requirement of validation of the results which is a long process and most of the times not agile as the once the experiment starts a set of defined sops is used to move forward in order to reduce distractions where as these two categories are agile and is can be used in any sector.

4.4 Internal Analysis of New Tools/method and Implementation studies(Quantitative & Qualitative):

	ICED17			ICED19		
	Might be	Definitely	Total	Might be	Definitely	Total
NT	17	92	109	9	86	95
IS	37	106	143	47	85	132

Table 2. Distribution of NT and IS into sub categories of Might Be and Definitely.

Implementation Study

ICED2017

Implementation studies can be very different when it comes to the generality of their results as shown in Table.2. In ICED 2017 41.95% of the papers dealt with methodology development, whereas 15.38% reported a specific project implementation. 34.26% papers attempted to generalize the findings and only 8.39% were discussions. Implementation studies are very skewed when object of the study is concerned, 80% deal with methods and 1% with software tools whereas 18% addressed methods alongside tools to implement it.. Reference to relevant empirical research is made by 97.1% of papers.

ICED2019

Moving Forward In ICED 2019 41.67% of the papers dealt with methodology development, whereas 16.67% reported a specific project implementation. 31.82% papers attempted to generalize the findings and only 9.1% were discussions. Implementation studies results are very skewed when object of the study is concerned, 90% deal with methods and 1% with software tools whereas 8.3% addressed methods alongside tools to implement it. Reference to relevant empirical research is made by 84.09% of papers.

New Tools

ICED 2017

As previously stated, the majority of research presented at ICED is focused on the creation of new tools and approaches. In ICED 2017 The work done in this research stream is be divided into three categories: creation of new methods (49.5%), software tools (9.17%), and methods integrated into software (41.33%). Only 31.58% of the papers were based on existing software products for the design task and out of these 31.58% almost 88.23% had the possibility of implementation with commercial application which is roughly 27.5% of the total published papers in this category. Only 26.6% referred to a specific industrial need whereas 71.55% were based on a generic need of any sector and 1% didn't care to address any need. 909% of the authors addressed the issue on the implementation of the tools or methods.

ICED 2019

In ICED 2019 The work done in this research stream is be divided into three categories: creation of new methods (80%), software tools (6.31%), and methods integrated into software (13.69%). Only 20% of the papers were based on existing software products for the design task and out of these 20% almost 84% had the possibility of implementation with commercial application which is roughly 21% of the total published

papers in this category. Only 28% referred to a specific industrial need whereas 70% were based on a generic need of any sector and 2% didn't care to address any need. 87% of the authors addressed the issue on the implementation of the tools or methods.

Qualitative Analysis

4.4.1 Policy making and Framework(Implementation Studies):

During the qualitative analysis it was found that 68.7% of the implementation studies were focused on the formation of a framework for different purposes. Those include a framework to introduce something, to change an already existing method or to induce new habits into different aspects of engineering related communities. There could be plenty of reasons why research these days is so much deviated towards policy making and Frame work which includes urgency of new methods for smooth processing, health related implementation studies to monitor real time health conditions of a patient, smart learning, industry 4.0, digitalization of business.

4.4.2 Software based new tools/methods(NewTools):

Considering both conferences of 2019 and 2017 45 out of 820 papers were software based new tools/methods which is merely 5.48 percent. And individually only 2.7 percent of ICED2019 and 8.25 percent of ICED2017 were new tools which were based on already existing software or integration of new software. There could be numerous reasons for these low numbers of research papers which were software centric. Those could include non software for market differentiation, licensing problems, Bugs, Broken Code, & Technical Debt which happen because of underscoring, Premature Optimization which happens because of Lack of strong code review process, Stuck With Complicated New Technologies which happens because of lack of experience at any level. But it could be anticipated that if this research work is carried forward we may find a huge number of research papers based on software because of the the new direction given by COVID19 for smart working conditions.

4.4.3 Processes(Implementation studies and New Tools)

As we have discussed in methodology part that one of the main purposes of these two categories are to bring efficiency into the engineering world by making continues improvements into the processes. A large amount of papers approximately 28.8% of the papers were based on new or improved processes which were considered as a part of either of the two categories. There could be numerous reason for these research

topics We can refer to the continuous cycles of improvement that a business makes to a service or product. Numerous businesses, from large corporations to start-ups, have similar systems in place. Some of the main types of the development and usage of new/improved processes based on previous knowledge are below.

- Monitoring of equipment
- Documentation writing and editing
- Assessments of the risks associated with present equipment/processes
- Evaluation of all processes and equipment on a continuous basis
- Installation of new equipment
- Troubleshooting manufacturing issues
- Conducting oversight of procedures and activities personnel
- Collecting and interpreting data
- Data findings presentation
- Fiscal responsibilities

As explained in the previous parts Cantamessa (2003) used the same classification for the research papers of ICED97 and ICED99. When the number and ratio of the types of research papers in previous and current conferences are examined, the following results are obtained:

	ICED97	**ICED99**	**ICED17**	**ICED19**
EM	53 (16%)	58 (15%)	71 (17%)	99 (24%)
EX	20 (6.0%)	22 (6.0%)	55 (13%)	51 (13%)
NT	141 (43%)	190 (49%)	109 (27%)	95 (23%)
IS	56 (17%)	51 (13%)	143 (35%)	132 (32%)
OTH	59 (18%)	68 (17%)	34 (8.0%)	30 (8.0%)
TOTAL	**329 (100%)**	**389 (100%)**	**412 (100%)**	**407 (100%)**

Table.3 Comparison of ICED97, ICED99, ICED17 and ICED19 papers

	ICED97 and ICED99	ICED17 and ICED19
EM	111 (15%)	170 (21%)
EX	42 (6.0%)	106 (13%)
NT	331 (46%)	204 (25%)
IS	107 (15%)	275 (33%)
OTH	127 (18%)	64 (8.0%)
TOTAL	**718 (100%)**	**819 (100%)**

Table.4 Comparison of ICED97 and ICED99 papers with ICED17 and ICED19 papers

Development of new methods and tools is the most common research paper type at both ICED97 and ICED99, as shown in the Table, and there is a substantial difference in the quantity of NT articles compared to other types during both conferences. In addition, the proportion of papers that do not fit into any of the four categories is the second highest for both conference papers. The ranks of NT and OTH studies do not change when the total number of research papers in both conferences is considered. Implementation studies come in third while empirical research come in fourth. Experimental investigations are last on the list, accounting for just 6% of all conference papers.

4.5 Reasons behind the difference of percentage of NewTools & Implementation Studies

Many factors might explain why, over a decade after the first study, the proportion of research publications falling into the categories of new tools and implementation studies has decreased. For example, before the millennium, there was an increasing concentration of industries, universities, governments, and research centers toward the sophistication of already developed tools and methods from experimentation; however, after 1995, there was a huge boom in smart technology, and concentration shifted away from sophistication of already developed tools and implementation towards problem solving, disruptive innovation, and data collection, all of which have shown to be beneficial for the world's population (from 15 percent to 21 percent). Industries were shifting toward a more user-centric approach (including customers, clients, B2B, B2C, D2C). Because of this, increasing resources were being allocated to the development of new devices, and to the manufacture of these new devices through experimental studies, increasing resources were being allocated to

research and development in order to gain an understanding of customer needs, demands, and satisfaction.

A very good example is how cell phones have increased in size and battery life, as well as the ability to add services other than making calls, such as operating applications and sending text messages. Cellphones have progressed from being pricey gadgets that supplement landlines for busy employees and travelers to becoming the only phones used or carried by many individuals. They've evolved from bulky, clunky gadgets with poor signal quality to compact, dependable instruments that fit comfortably in a pocket or handbag.

Normality tests were performed in SPSS for ICED17 and ICED19 papers and it was determined that the kurtosis and skewness values were defined between -1.5 and 1.5.

According to Tabachnick (2007)[31], it can be said that the types of research papers are normally distributed. Considering the number and ratio of the types of research papers, it is seen that they do not differ excessively from each other. However, it is seen that implementation studies have the majority, and they constitute the 33 percent of the total research papers. Development of new tools and methods is the second dominant category and empirical studies are in the third place. Although experimental studies are in the second place from the last, it is seen that both the number and rate of experimental studies have more than doubled when compared to previous conferences. In addition, the number and rate of studies that do not belong to any specified category have decreased by more than half compared to previous conferences. This could mean that research papers published in ICEDs have started to be more focused on design research rather than focus on only explaining the design theories or education.

4.9 Types of Theory Referenced in Research Papers

Another classification made is about theories that research papers include as mentioned in methodology part. While some of the papers do not mention any kind of theories, some of them mention design theories and some of them give references to theories not related to design but to other areas of the science. Distribution of the research papers by type of theories they include for ICED17 and ICED19 is given in Table …

	No Theories	**Other Theories**	**Design Theories**
ICED17	149	213	50
ICED19	74	302	31
TOTAL	223	515	81

Table.5 Distribution of papers by type of theories they include and conferences

As Table shows most of the research papers in both conferences refer to theories, but only 14 percent of these research papers include design theories. Most of the articles mention other theories.

In Table the types of research papers are grouped according to the types of theory they mention.

	No Theories	**Other Theories**	**Design Theories**
NT	50	126	28
IS	81	179	15
TOTAL	223	515	81

Table.6 Distribution of papers by type of theories they include and research types

As Table shows for all types of research papers, the majority consists of research papers that refer to other types of theories. For all research paper types, the second dominant group is research papers that do not contain any theory.

For **New Tools** category in ICED2017 16.5% papers gave reference to at least one design theory whereas 49.5% referred to other theories and 34% didn't have any theory reference.

in ICED2019 10.5% papers gave reference to at least one design theory whereas 75.8% referred to other theories and 13.7% didn't have any theory reference.

For **Implementation studies** category in ICED2017 4.2% papers gave reference to at least one design theory whereas 48.95% referred to other theories and 46.9% didn't have any theory reference.

in ICED2019 6.81% papers gave reference to atleast one design theory whereas 82.6% referred to other theories and 10.59% didn't have any theory reference.

4.10 Methodology Description

Research papers were grouped according to whether they contain a clear description of the methodology or approach they are using. The distribution of research papers for each conference according to whether there are methodology explanations or not is given in Table

	Clear Methodology Description	**No Clear Methodology Description**
ICED17	407	5
ICED19	385	22
TOTAL	792	27

Table.7 Distribution of papers by methodology description

As can be seen in Table almost 97 percent of the research papers include clear methodology description. This ratio is almost 99 percent at ICED17 and almost 95 percent at ICED19. These results show that almost all of the research papers take part in ICED17 and ICED19 were written in a systematic method and method they include was clearly explained.

	Clear Methodology Description	**No Clear Methodology Description**
NT(ICED2017)	109 (100%)	0 (0%)
IS(ICED2017)	143(100%)	0(0%)
NT(ICED2019)	92(96.84%)	3(3.16%)
IS(ICED2019)	124 (93.9%)	8(6.1%)

Table.8 Distribution of NT and IS papers by methodology description

As far as Clear methodology or approach on research is concerned for ICED2017 both NewTools and Implementation studies 100% of the publications gave a clear methodology was given. Whereas in ICED2019 both categories had a minor number of papers (NT3.16% and IS6.1%) who didn't

showed any clear methodology. This seems to be very obvious because no research could be done with out a clear methodology even if it's a discussion paper.

4.11 Data Collection

In addition to research paper's methodology description, whether data collection was done in the studies is examined. For the papers include data collection part, two groups were determined as the ones clearly describe research methodology, they used for data collection and the ones do not describe it clearly. It is shown in Table …

		Data Collection	
	No Data Collection	Clear Description of Research Methodology	No Clear Description of Research Methodology
ICED17	34	364	14
ICED19	26	349	32
TOTAL	60	713	46

Table.9 Distribution of papers by data collection methodology

According to the results in Table … the number of research papers that do not mention data collection is very low, almost 7 percent of total conference papers. Of the research papers that included data collection, the research methodology for data collection was clearly defined in approximately 96 percent of ICED17 papers and almost 92 percent of ICED19 papers.

	Data Collection		
	No Data Collection	Clear Description of Research Methodology	No Clear Description of Research Methodology
NT(ICED2017)	6	81	22
IS(ICED2017)	0	137	6
NT(ICED2019)	2	76	17
IS(ICED2019)	0	120	12

Table. 10 Distribution of NT and IS papers by data collection methodology

As it can be seen that for ICED 2017 majority of the papers gave a clear description of research methodology on data collection (NT74.31% & IS95.8%). Whereas for ICED2019 there were more percentage of papers which didn't gave a clear description numerically 80.07% of NT and 90.1% of IS gave a clear description. And almost 1.03% of the paper didn't collect any data.

4.12 Data Analysis

The same classification was made for data analysis. The research papers were categorized according to whether they included data analysis and, if so, whether the research methodology related to the data analysis was clearly defined.

	Data Analysis		
	No Data Analysis	Clear Description of Research Methodology	No Clear Description of Research Methodology
ICED17	36	367	9
ICED19	29	343	35
TOTAL	65	710	44

Table.11 Distribution of papers by data analysis methodology

As can be seen in Table … similar results were obtained for data analysis as in the data collection part. Because most of the research papers that contain data collection part aim to analyze data collected. Almost 91 percent of ICED17 papers and almost 93 percent of ICED19 papers include data analysis and among these papers research methodology of data analysis was clearly described in almost 98 percent of ICED17 papers and approximately 91 percent of ICED19 papers.

	No Data Analysis	Clear Description of Research Methodology	No Clear Description of Research Methodology
NT(ICED2017)	4	85	20
IS(ICED2017)	0	140	3
NT(ICED2019)	2	78	15
IS(ICED2019)	0	116	16

Table.12 Distribution of NT and IS papers by data analysis methodology

4.13 Industrial Involvement

Research papers were also classified whether they included industrial involvement. In doing so, criteria such as whether an analysis or case study was conducted in a company, whether universities and companies were working in coordination, or whether one of the authors in the study was a company employee were looked at. Results are shown in Table

	Industrial Involvement					
	EM	**EX**	**NT**	**IS**	**OTH**	**TOTAL**
ICED17	52.1%	16.3%	22%	25.2%	23.5%	**27.7%**
ICED19	35.3%	37.3%	28.4%	21.2%	20.0%	**28.3%**
TOTAL	**42.4%**	**26.4%**	**25.0%**	**23.3%**	**21.9%**	

Table.13 Distribution of papers by industrial involvement percentages

From the Table.13 it is seen that the type of research that includes the most industrial participation for ICED17 is empirical studies with a rate of 52.1 percent. This is followed by implementation studies with 25.2 percent. According to these results, it can be said that more than half of the empirical studies are conducted in a company and the rest are related to educational research. On the

other hand, for ICED19 it is seen that industrial involvement rates distributed more equally among the research types. Experimental studies have the highest industrial involvement share with 37.3 percent and empirical studies comes the second place with 35.3 percent.

When industrial involvement is analyzed based on conferences, it is seen that the industrial involvement rates of the two conferences are very close to each other, 27.7 percent for ICED17 and 28.3 percent for ICED19. If analysis is made upon research types, it is seen that 42.4 percent of the empirical studies include industrial involvement. It is observed that other types of research have very similar industrial involvement rates, between 21 and 26 percent.

4.14 Referencing Patterns

A comparison of the percentages of ICED97 and ICED99 papers and ICED17 and

ICED19 papers that refer to previous ICEDs is given in Table …

According to the results of the analysis by Cantamessa (2003) the average rate for ICED97 and ICED99 papers that refer to previous ICEDs has been calculated around 31 percent. It is seen that this rate has increased only slightly to 36 percent in 20 years. At all conferences, the number of research papers citing previous ICEDs is less than half of the total amount of papers. Cantamessa (2003) mentioned that this ratio for ICED97 and ICED99 papers are less than one-third of the papers and it shows a low and disappointing degree of consistency with previous work. Examining the ratios above, it would not be wrong to say that the situation has not changed much after 20 years.

According to the results in Table the proportions of research papers referring previous editions of ICED are 35 percent for ICED17 and 37.1 for ICED19. There is a slight increase in this rate in 2 years. On the other hand, the remaining papers do not give any reference to previous ICEDs.

Table.14 Distribution of papers by References to Previous ICEDs percentages

	References to Previous ICEDs	
	ICED97 and ICED99	**ICED17 and ICED19**
References	31.7%	36.0%
No References	68.3%	64.0%

The table below shows a comparison of specifically only the categories this paper is focusing on

	Ref to own ICED	Ref to own OP	No Ref to Own
NT(ICED2017)	47	22	63
IS(ICED2017)	45	20	92
NT(ICED2019)	42	18	60
IS(ICED2019)	48	14	89

Table.15 Distribution of NT and IS papers by References to Previous ICEDs percentages

NEWTOOL(ICED2017)

According to the analysis in ICED 2017 43% of the papers in NEWTOOLS had a reference of work from a previous ICED conference where as breaking down this into three sub categories 20.18% papers had a reference to authors own work ina previous ICED, 57.7% papers had reference to authors work in non-ICED publication and 22% of the papers had no reference to authors previous work.

IMPLEMENTATION STUDY (ICED2017)

According to the analysis in ICED 2017 of the papers in IMPLEMENTATION STUDY, 31.46% had a reference of work from a previous ICED conference where as breaking down this into three sub categories 13.98% papers had a reference to authors own work in a previous ICED, 57.7% papers had reference to authors work in non-ICED publication and 21.6% of the papers had no reference to authors previous work.

NEWTOOL(ICED2019)

According to the analysis in ICED 2019 43.11% of the papers in NEWTOOLS had a reference of work from a previous ICED conference where as breaking down this into three sub categories 18.94% papers had a reference to authors own work in a previous ICED, 63.15% papers had reference to authors work in non-ICED publication and 17.89% of the papers had no reference to authors previous work.

IMPLEMENTATION STUDY (ICED2019)

According to the analysis in ICED 2017 of the papers in IMPLEMENTATION STUDY , 36.36% had a reference of work from a previous ICED conference where as breaking down this into three sub categories 10.61% papers had a reference to authors own work in a previous ICED, 67.42% papers had reference to authors work in non-ICED publication and 21.96% of the papers had no reference to authors previous work.

General Analysis of Referencing pattern

In Table the percentages of the research papers that refer to previous publications of the authors are shown both for the averages of ICED97 and ICED99 and those for ICED17 and ICED19.

	ICED97 and ICED99	ICED17 and ICED19
References to Own ICED Works	17.9%	16.2%
References to Own Other Publications	35.5%	58.4%
No References to Own	46.6%	25.4%

Table.16 Percentages of papers that refer to previous publications of the authors at ICED97 and ICED99 and ICED17 and ICED19

According to the results in Table, it is seen that the percentages of papers including references to the authors' own previous works increased from 53.4 percent to 74.6 percent in 20 years. However, the ratio of the research papers that give reference to the authors' previous ICED works decreased by 1.7%.

From the above-mentioned results it can be said that for the percentages of both references to previous ICEDs and references to authors' previous own ICED works are lower than expected. In addition, it is seen that there is no improvement in these rates in 20 years. To compare these referencing patterns with those in other conferences, Cantamessa (2003) conducted an analysis. In this study, three conferences from other engineering fields and one conference with the closest domain to ICED from operations management background were analyzed. The results obtained

proved that the referencing patterns for ICED works were no worse than for other conferences. Since it is possible to compare the reference models of the examined conference with those of 20 years ago, comparing the results of this study with other conferences was not included in this study. The scope of the study in reference models is to examine the change in 20 years

Geographical Analysis of Referencing Pattern

In all scientific fields over the years, researchers have advanced based on the results of their colleagues and the researchers have demonstrated this increasing correlation between research findings by referencing to previous studies. Therefore, references can be used as a measure to assess the extent to which researchers are aware of previous literature. In this study, some referencing patterns of ICED17 and ICED19 papers were analyzed. First of all, the proportions of research papers referring previous editions of ICED were examined by geographical regions and shown in Table

References to Previous ICEDs									
	WE	**NE**	**USA, CAN**	**ASIA**	**SE**	**SA**	**AUS, NZ**	**OTHER**	**TOTAL**
ICED17	40.0	34.9	19.6	25.9	50.0	9.1	50.0	50.0	**35.0**
ICED19	43.6	34.8	29.3	20.0	43.8	40	27.3	14.3	**37.1**
TOTAL	**41.8**	**34.8**	**23.7**	**22.6**	**46.6**	**23.8**	**33.3**	**27.3**	

Table.17 Percentage of papers referencing previous ICEDs by geographical regions

The analysis of the citation percentages at both conferences reveals that more than 41 percent of the research papers written by Southern Europe, Western and Central Europe refer to previous ICEDs. Also more than 33 percent of research papers written by Northern Europe, Australia and New Zealand reference previous ICEDs.

Another reference model examined is the rate at which papers' authors cite their own previous work published in previous editions of ICED. The percentages of research papers that include references to previous ICED work by one of the authors by geographical region are shown in Table.18

References to Previous Own ICED Works									
	WE	**NE**	**USA, CAN**	**ASIA**	**SE**	**SA**	**AUS, NZ**	**OTHER**	**TOTAL**
ICED17	18.9	17.4	10.7	18.5	26.9	0.00	0.00	25.0	**17.2**
ICED19	20.7	8.7	7.3	5.7	21.9	20.0	18.2	14.3	**15.2**
TOTAL	**19.8**	**13.4**	**9.3**	**11.3**	**24.1**	**9.5**	**13.3**	**18.2**	

Table.18 Percentages of papers that gives references to authors' previous own ICED works by geographical regions

The proportion of research papers including citations to their own past ICED studies by their authors is quite low, as shown in the Table, both as an average of both conferences and on the basis of research papers from each area. When compared to the old referring pattern (references to earlier ICEDs), the rates are less than half of what they were. This means that the authors of ICED17 and ICED19 did not participate in the prior ICEDs in more than 17 percent of the time.

The papers that refer to their authors' writings at other conferences and research papers that do not refer to any past work by their authors fall into the final two categories of reference models.

The last two classifications of reference models consist of the papers that refer to its authors' publications at other conferences, and research papers that do not refer to any previous work by their authors.

The percentages of citations by each defined geographical region are given in Table

References to Own Other Publications									
	WE	**NE**	**USA, CAN**	**ASIA**	**SE**	**SA**	**AUS, NZ**	**OTHER**	**TOTAL**
ICED17	60.0	58.7	60.7	59.3	42.3	45.5	25.0	50.0	**57.8**
ICED19	56.4	63.0	61.0	54.3	71.9	50.0	45.5	57.1	**59.0**
TOTAL	**58.2**	**60.7**	**60.8**	**56.5**	**58.6**	**47.6**	**40.0**	**54.5**	

Table.19 Percentages of papers that gives references to authors' own other publications by geographical regions

	No References to Own Publications								
	WE	**NE**	**USA, CAN**	**ASIA**	**SE**	**SA**	**AUS, NZ**	**OTHER**	**TOTAL**
ICED17	21.1	23.9	28.6	22.7	30.8	54.5	75.0	25.0	**25.0**
ICED19	22.9	28.3	31.7	40.0	6.3	30.0	36.4	28.6	**25.8**
TOTAL	**22.0**	**25.9**	**29.9**	**32.3**	**17.2**	**42.9**	**46.7**	**27.3**	

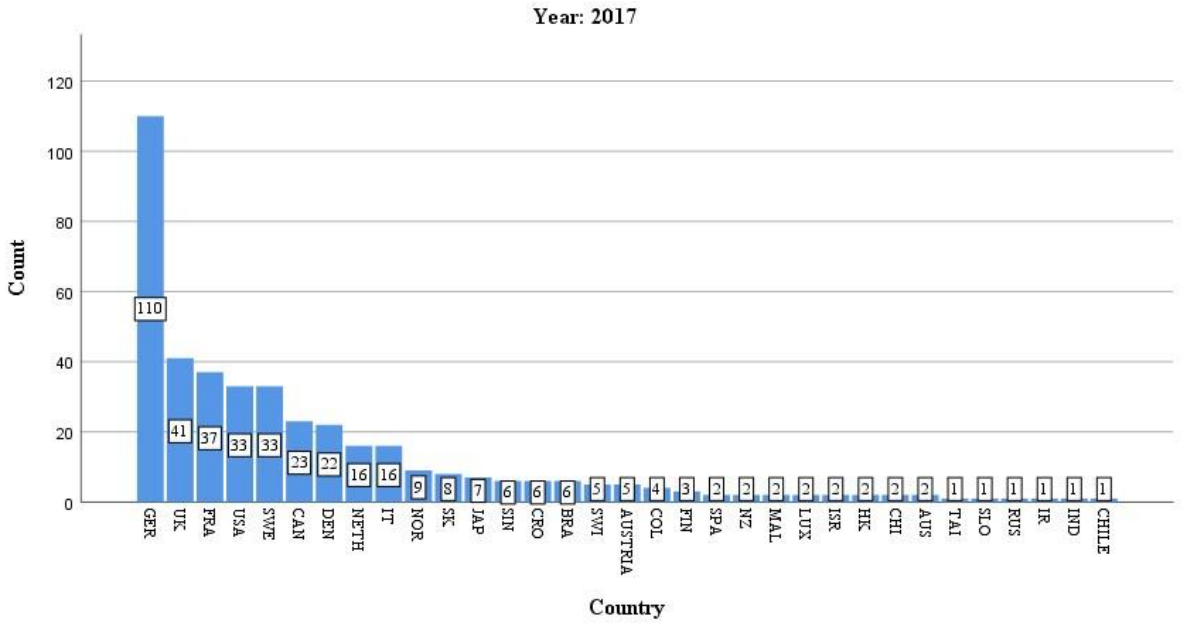
Table.20 Percentages of papers that does not give references to authors' own publications by geographical regions

As it is seen from the tables ICED17 and ICED19 mostly consist of the research papers that refer to previous other works of their authors. It is seen that approximately 61 percent of the papers written by the universities in USA, Canada and Northern Europe give reference to their authors' own other publications. In other universities, this rate is over 40 percent.

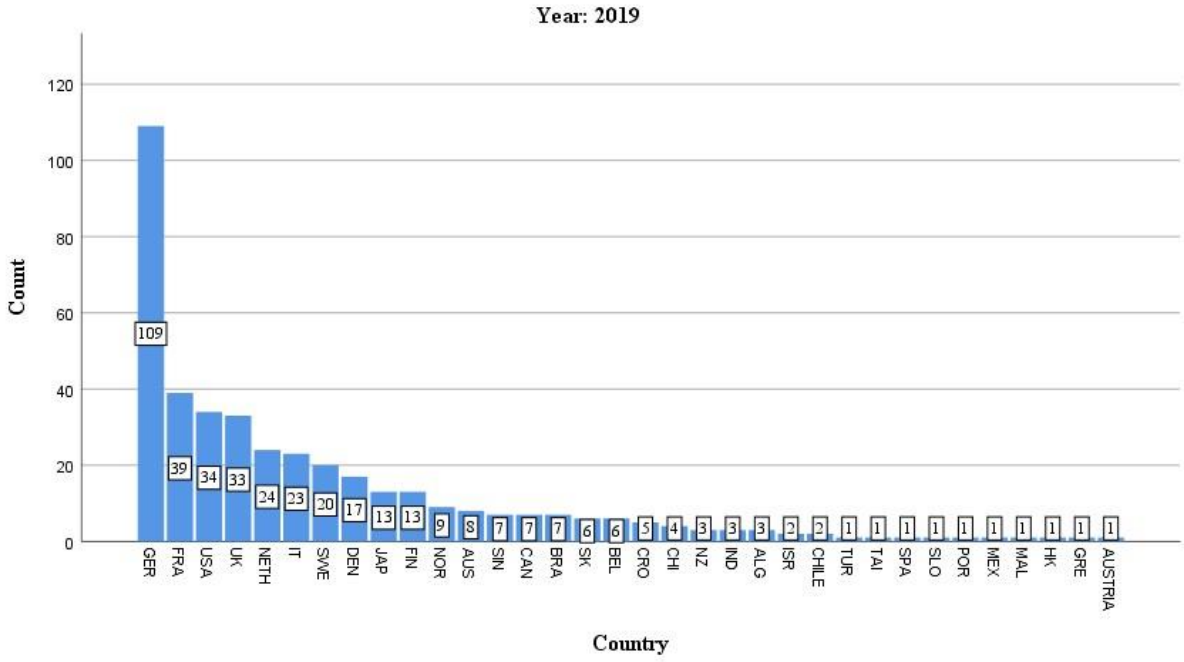
Research papers whose authors do not refer to their own publications do not constitute the majority, but the proportion is higher than for articles that refer to previous ICED studies of their authors. While the percentage of the papers that do not include references to their authors' previous publications is only 22 percent for Western Europe universities, it is 46.7 percent for the universities in Australia and New Zealand and 42.9 percent for those in South America.

4.6.1 Universities or Research Centers

Besides type of the research papers, another piece of information collected for each research paper was which university or research center the article was written by. To make a comparison between the different countries involved in the conferences the countries which the universities or research centers located were determined and they are listed for each of the conferences. The abbreviations are used for the graphs and tables and these are alphabetically; ALG: Algeria, AUS: Australia, BEL: Belgium, BRA: Brazil, CAN: Canada, CHI: China, COL: Colombia, CRO: Croatia, DEN: Denmark, FIN: Finland, FRA: France, GER: Germany, GRE: Greece, HK: Hong Kong, IND: India, IR: Ireland, ISR: Israel, IT: Italy, JAP: Japan, LUX: Luxembourg, MAL: Malaysia, MEX: Mexico, NETH: Netherlands, NOR: Norway, NZ: New Zealand, POR: Portugal, RUS: Russia, SIN: Singapore, SK: South Korea, SLO: Slovakia, SPA: Spain, SWE: Sweden, SWI: Switzerland, TAI: Taiwan, TUR: Turkey, UK: United Kingdom and USA: United States. The distribution of the research papers by different countries for each of the conference are listed in Grap.2

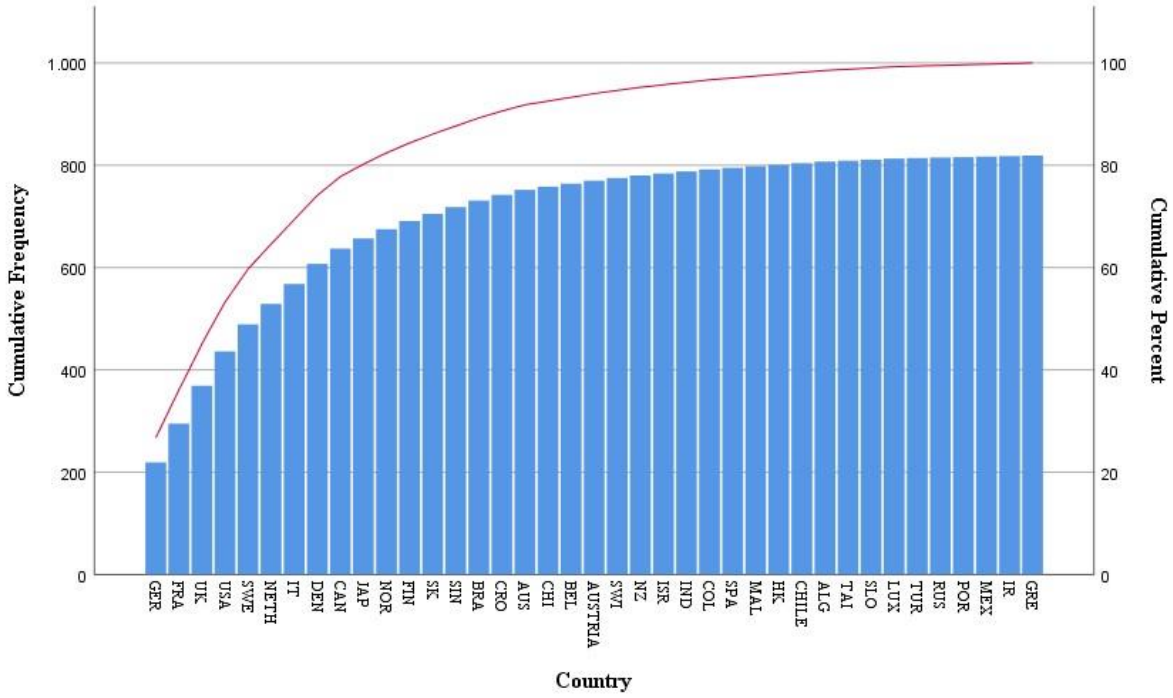


Graph.2 Distribution of ICED17 papers written by universities or research centers in different countries



Graph.3 Distribution of ICED19 papers written by universities or research centers in different countries

As it is seen from the graphs the number of research papers written by German universities for both ICED17 and ICED19 is much higher than that written by other countries. UK, France and USA are the second dominant countries for both of the conferences in terms of research paper numbers.



Graph.4 Pareto analysis of research paper production by research centres or universities in different countries

Based on the Pareto analysis in Graph it is seen that 80 percent of the research papers are written by approximately 20 percent of the countries where universities are located. These countries are Germany, France, UK, USA, Sweden, Netherlands, Italy, Denmark and Canada. It is also seen that the biggest contribution is made by German universities with more than 20 percent.

4.6.2 Geographical Regions of The Universities or Research Centers

Since the above-mentioned countries differ from each other in size and population, they are grouped according to their geographical proximity, and the analysis is repeated on the basis of 8 different

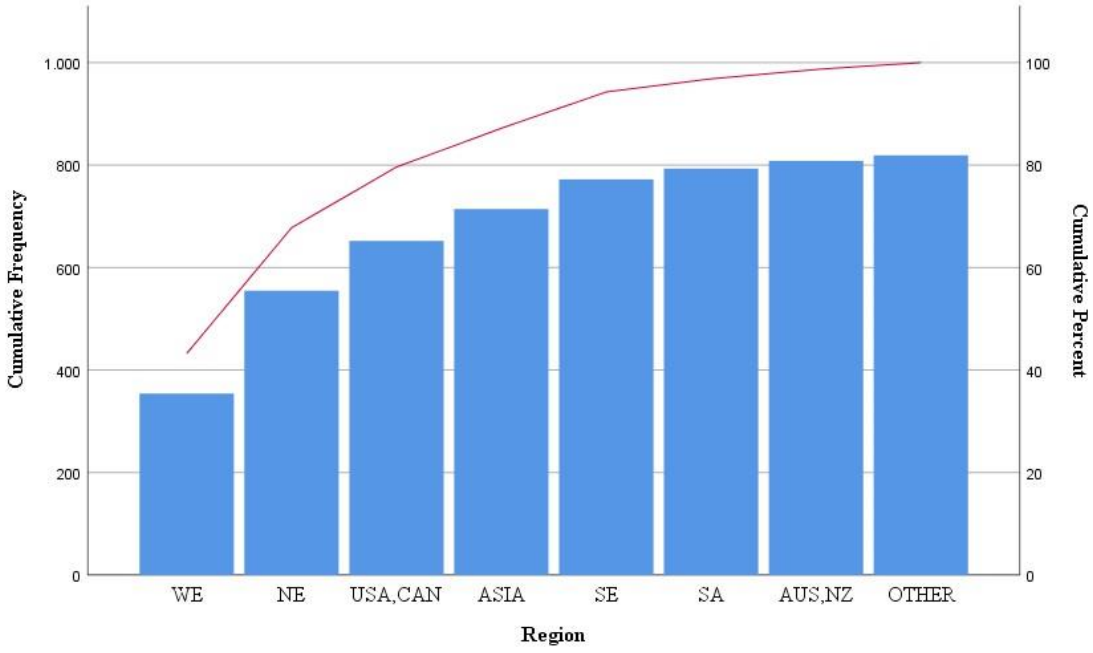
regions. These regions are Asia (ASIA), Australia and New Zealand (AUS,NZ), Northern Europe (NE), Western and Central Europe (WE), Southern Europe (SE), South America (SA), USA and Canada (USA,CAN) and other countries (OTHER). The countries in the category of others are Algeria, Israel, Russia, Slovakia and Turkey. The distribution of papers in both ICED17 and ICED19 by the defined regions are in

Table …

	WE	**NE**	**USA,CAN**	**ASIA**	**SE**	**SA**	**AUS,NZ**	**OTHER**
2017	175	109	56	27	26	11	4	4
2019	179	92	41	35	32	10	11	7
TOTAL	354	201	97	62	58	21	15	11

Table.21 Distribution of papers by geographical regions

From Table it can be said that for both of the conferences (ICED17 and ICED19) the biggest portion of the universities participated are from Western and Central Europe. Considering the country distribution of the research papers given above, it is not difficult to predict this result. Because Germany, France and Netherlands fall into this category, and they make the biggest contribution. Second majority is constituted by the research papers written in Northern Europe. In this study, UK, Sweden and Denmark are analyzed in NE category and as it can be seen from the previous results, the participation of these countries is one of the majorities.



Graph.5 Pareto analysis of research paper production by research centers or universities in different geographical regions

Based on Pareto analysis given in Graph it is seen that the participation of Western and Central Europe constitutes more than 35 percent of all regions. According to the analysis, 80 percent of research papers are written by approximately 35 percent of the regions identified. The Pareto principle cannot be verified here, but if the regions were determined on the basis of the number of universities they contain, a rate of 20 percent could be obtained. However, while creating regions, the aim is to reduce those in the "others" category as much as possible and to show the contribution of fast-developing regions such as Asia and Oceania.

In the study conducted by Cantamessa (2003) the geographical regions of ICED97 and ICED99 papers analyzed in 5 groups: DACH consists of Germany, Austria and Switzerland; UK, IRL (UK and Ireland); S, FIN, N, DK consists of Sweden, Finland, Denmark and Norway; USA, BR (USA and Brazil) and other countries. However, studies on ICED17 and ICED19 papers aimed to analyze the regions more detailly. There are two reasons of it. One of them is decreasing the number of countries in “others” category and try not to underestimate some regions contribution. Second reason is participation from the regions which were specified as “Other” for ICED97 and ICED99 conferences has increased significantly in 20 years. Regardless of all these reasons, the classification made for ICED97 and ICED99 was also made for ICED17 and ICED19 papers. The aim is to compare the regions participating in ICED17 and ICED19 with those that participated 20 years ago. The results are as in the Table...

	DACH	**UK, IRL**	**S, FIN, N, DK**	**USA, BR**	**Other**
ICED97 and ICED99	27.0%	21.0%	12.0%	12.0%	28.0%
ICED17 and ICED19	28.0%	9.0%	15.0%	10.0%	38.0%

Table.22 Comparison of ICED97 and ICED99 papers with ICED17 and ICED19 papers by 5 geographical regions

As can be seen from the table…, despite the intervening 20 years, the largest part of the research papers for all conferences is composed of universities in Germany, Austria and Switzerland. Although the countries of the universities participating in ICED97 and ICED99 are not known exactly, Germany's contribution is the reason why the DACH region is the majority in ICED17 and ICED19.

For ICED97 and ICED99, the contribution of UK and Ireland comes in the second place. However, it is seen that their contribution decreased sharply after 20 years. Although the reason for this decline is unknown, it can be interpreted that the UK may have focused on attending other conferences on engineering design in recent years due to its negative relations with the European Union.

Sweden, Finland, Denmark and Norway constitute the second majority for ICED17 and ICED19 and the third for ICED97 and ICED99. It seems that their contribution in percent is increased in 20 years slightly. On the other hand, the contribution of USA and Brazil dropped by 2 percent.

As mentioned earlier, the share of countries that are not in these 4 categories in ICED17 and ICED19 has increased compared to 20 years ago. In particular, the contributions of France, Netherlands, Italy and Canada cannot be underestimated. Besides the fact that countries make up the majority, one of the aims of this study is to describe the increase in contributions from regions such as Asia and Oceania. Although their contributions were not critical for a research conducted at the end of the 90s, the structure of the world economy has changed today and the contribution of these regions has gained much more importance compared to 20 years ago.

For ICED17 and ICED19, the distribution of the research papers by their research types and geographical regions where the universities are located are analyzed. The results are as in Table …

	WE	**NE**	**USA,CAN**	**ASIA**	**SE**	**SA**	**AUS,NZ**	**OTHER**
EM	57	59	24	15	10	2	2	1
EX	32	22	19	12	15	2	1	3
NT	107	40	15	15	16	2	6	3
IS	135	63	27	17	16	9	4	4
OTH	23	17	12	3	1	6	2	0
	354	201	97	62	58	21	15	11

Table.23 Distribution of papers by geographical regions and research types

To determine the association between the geographical regions and research types Chisquare test is conducted. Research type shows significant association with geographical regions where the research papers are written. However, based on Phi and Cramer's V tests the level of association is determined as weak. Therefore, the expected values of the number of the papers if two categorical variables were statistically independent is not mentioned here as in the study of Cantamessa (2003).

As it is seen from the Table…, since implementation studies are in the majority compared to other types of research papers in ICED17 and ICED19, it is seen that IS papers have the dominancy for research papers written by all regions. In terms of NT research papers, Western and Central Europe again ranks first and Northern Europe ranks second.

4.6.3 Difference of approach on Design Research predicted in Geographical Analysis

Numerous designers cited the origins of design practice in their own geographies as affecting how they work now. Europe has a considerably older design history that is inextricably linked to the arts and crafts movement. Additionally, a tradition of industrial design stretching all the way back to the Bauhaus movement implies a rich history of goods created in a single location, such as Germany, where design, engineering, and production occurred.

Matt Nesbitt, a UX design and strategy leader, shared an unusual viewpoint on average, European customers have greater expectations for the design of their goods. Smaller dwellings imply that "there is more demand on products that enter people's homes to solve issues very effectively and in a little amount of space." This is something I have personally seen, the innovation and well-designed European houses' clever use of space. The dish rack was integrated into the cabinet over the sink at an AirBnB I stayed in on a visit to Helsinki!

By contrast, US design is founded in the methods of Raymond Loewe and consultancies like as Teague, which emerged from Business War II and the advertising world. Consider Mad Men! Jamie Nicholson, a senior design strategist, views this as an important step in grounding design in the commercial world and instilling it with a business mindset. This emphasis has continued with organizations like as IDEO, based in the United States, adding corporate innovation to the way design thinking is marketed as a strategy. Additionally, one

designer claimed that digital design is founded in ad firms in North America, with a marketing orientation.

In absolute terms, Europe collectively generates more research outputs (articles, reviews, and conference papers indexed in Scopus) than the United States alone, which is the world's most prolific research country.

And the chasm is widening. In 2011, according to the study conducted by Geoff Maslen Europe accounted for 33.4 percent of global research output, while the United States accounted for 23.4%.

We can classify works as single authors, collaborations between authors at a single institution, collaborations inside a single nation (Europe) or state (US), collaborations between countries in Europe or US states, and collaborations involving at least one researcher from outside Europe or the US.

We discover that inter-country cooperation accounted for 13% of papers published in Europe in 2011, whereas inter-state collaboration accounted for 16% of papers published in the United States in 2011. Additionally, this tiny differential is shrinking - the percentage increased by more than two points in Europe between 2003 and 2011, whereas the proportion decreased somewhat in the US during the same time.

This indicates that the structures in place at the national and European levels to promote cross-country cooperation in Europe seem to be functioning. However, as one would imagine, there is tremendous variety among disciplines."

While cooperation patterns between European nations are roughly comparable to those between US states, the paper notes that institutional mobility of academics between European countries is far less common than migration between US states.

While funding agencies' attitudes toward cross-border grantmaking may contribute to this, more probable variables include variations in culture, language, administrative systems, benefits, pensions, and other support systems, all of which continue to vary significantly throughout Europe.

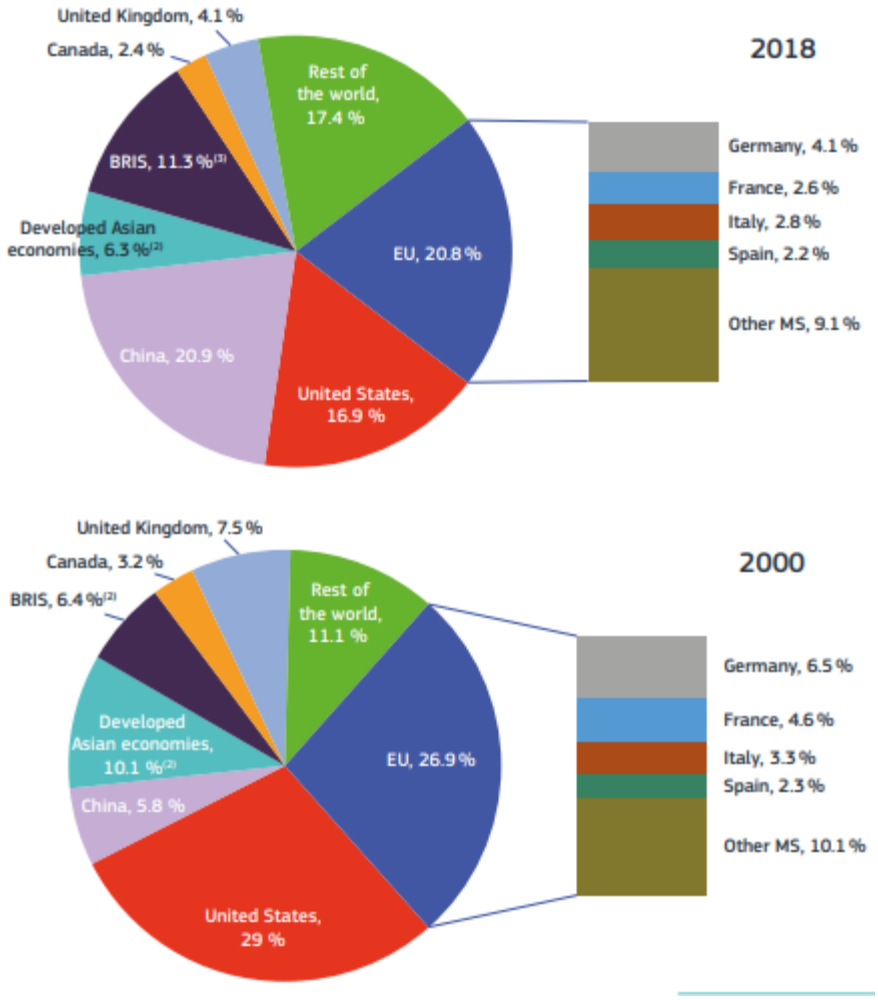
By comparison, employment legislation and remuneration packages are more comparable between states in the United States."

The evidence that researchers in Europe and the United States collaborated with researchers in some of the smaller research nations, such as Albania and Macedonia, even when cooperation did not result in increased citation impact for those countries.

Indeed, both the European and US cooperation networks are almost exhaustively inclusive, in the sense that every state or nation interacted with every other state or country within the two areas in 2011.

Mobility and cooperation, according to Elsevier spokesman Nick Fowler[32], are critical processes for boosting the efficiency and efficacy of research.Elsevier's work with Science Europe yielded fresh insights into the mobility and collaboration patterns of European and American academics, Fowler said, adding that the study served as a useful foundation for further improving the quality of research outputs.

Professor Paul Boyle, president of Science Europe, said that the results gave insight into the existing state of cooperation and mobility within research groups and would serve as a foundation for successful policy development.



World share of scientific publications %, 2000 and 2018 according to EU innovation council

4.6.3.1 The Policy Effects

A useful lens through which to see the design environment is if there is wider policy or governmental support for design. Europe seems to be setting the standard in this area; as Christina Sadek, a service designer, puts it, "Design is pushed in Europe." Markus Grupp, an experience design leader, made a similar point about groups such as the Design Council in the United Kingdom, which oversees major design efforts. The Design Council is an independent organization (in fact, a charity) established to show the importance of design and serves as the UK government's design adviser. Their objective is to "promote innovative design thinking, foster discussion, and educate public policy." The European Commission, an EU institution charged with proposing laws and enforcing EU decisions, has also highlighted design as a critical driver of innovation policy. In North America, there seems to be less emphasis on design as a governmental goal and a more private sector and technology-driven development of design and design practice.

4.6.3.2The Importance of Technology, Innovation, and Entrepreneurship

In addition to the policy issue, Ryan Rumsey, a director of experience design, said that "in North America, designers work in contexts with fewer restrictions or laws, which allows for more latitude in problem solution." Because European privacy and security rules are more severe, designers are more constrained in terms of the solutions they can supply." Jamie Nicholson also emphasized the difference in people's perceptions of what constitutes a core value - "in the US, innovation is everything, but in Europe, service design and digital experience are more important." This results in a change in the vocabulary and framing of design initiatives, as well as in the total skills and competences required.

The idea that North America is really committed to and driven by innovation, especially in the technology sector, emerged as a recurring theme. Matt Nesbitt highlighted a "perception that innovation occurs in the United States, and that America is the destination for the 'best' personnel." This is accompanied by an increase in design investment in the startup and technology sectors. Matt highlighted emerging technologies in the United States, such as voice interfaces and virtual reality, that provide cutting-edge design possibilities. As a contrast, Daniel Harvey, a London-based designer with 15 years of experience in New York City, points out that Europe jumped the gun on designing the Internet of Things. This achievement was made possible by the efforts of individuals such as Alex Deschamps Sonsino and BERG. Additionally, Cambridge is a global leader in artificial intelligence research.

4.6.3.3 The Industries' Various Stages of Development

Numerous designers alluded to the level of development or maturity of certain design sectors. Markus Grupp, a Toronto-based UX and digital design consultant, noted that in Canada circa 2005, there were few communities devoted to UX and digital design, but in the UK at the time, there was an explosion of events and communities. This has expanded significantly in recent years, and when I moved to Toronto in 2012, I discovered a plethora of meetings, interest groups, and events focused on UX and digital in particular, which has continued to grow and improve.

In contrast to North America, where UX design is a well-established professional path with many designers having purely digital backgrounds, Ryan Rumsey noted that "those with pure digital design backgrounds are few and far between in a European environment." It is possible that North America's digital sector began later, but expanded and matured more swiftly as a result of increased demand.

4.6.3.4 Speed Expectations

A surprising element that emerged from the study was that of practice pace. As chief creative officer Daniel Harvey put it, "New York City and San Francisco design cultures are ever so slightly more reliant on the "move quickly and break things" and "always be shipping" mantras than the UK. Here, design thinking, research, and a smattering of academic dogmatism are more pronounced." This reflected Matt Nesbitt's observation that "the startup crunch for a home run unicorn, paired with the American Puritanical hard work hangover, accelerates the emergence of new choices." Ryan Rumsey concurred, stating that "work in Europe is more meticulous and less concerned with speed." Surprisingly, it is one of very few areas wherein there seemed to be unanimous agreement among many of the designers , with Markus Grupp adding that design in Europe is less constrained by deadlines and processes, since there is a more acknowledged understanding of design as a profession with a rigorous process.

4.7 Ranking of The Universities or Research Centers

In addition to the countries and geographical regions of the universities and research centers, their rankings were considered as well. To make an objective classification the “World University Rankings” from Times Higher Education was taken into account. The universities which are ranked in the first 100 universities defined as “Very High” ranking universities. The universities which have a ranking between 100 and 200 were labelled as “High” ranking universities and those located between the rank 200 and 1000 were stated as “Medium” ranked universities. Others defined as “Low” ranking ones. While defining the rankings, negligible errors may have occurred due to the size of the dataset, but this error is expected to be less than 0.01.

Graph.6 Pareto analysis of the research papers by the rankings of research centers or universities

From the Pareto diagram shown in Graph it is seen that medium-ranking universities constitute the majority with 38.10 percent. They are followed by low-ranking universities with 27.47 percent. Although the majority of universities are in the middle and low rankings, the top 100 universities participating in the ICED17 and ICED19 conferences are a non-negligible proportion. The studies carried out by such universities participating in the conferences constitute 19.78 percent of the total studies. High and very top ranked universities, taken together, account for almost 35 percent.

Although the rankings are taken from an objective resource, for the classifications on the rankings subjectivity cannot be excluded. The "very high" classification was limited to the top 100 universities, as the share of universities in the top 100 was sufficient to make an analysis. However, universities in the ranking between 100-200 can also be counted in the "very high" category. The reason why the number of medium ranked universities is so high is that this classification includes all the universities ranked between 200 and 1000. Therefore, it can be said that 85 percent of the participation in ICED17 and ICED19 consists of universities in the top 1000.

RANKING of THE UNIVERSITIES	TYPE of THE RESEARCH PAPERS					REGIONS of THE UNIVERSITIES		
	EM	**EX**	**NT**	**IS**	**OTH**	**WE**	**NE**	**USA,CAN**
LOW	42 (18.7%)	31 (13.8%)	55 (24.4%)	86 (38.2%)	11 (4.9%)	106 (47.1%)	39 (17.3%)	30 (13.3%)
MEDIUM	65 (20.8%)	32 (10.3%)	84 (26.9%)	99 (31.7%)	32 (10.3%)	107 (34.5%)	95 (30.4%)	20 (6.4%)
HIGH	28 (23.3%)	16 (13.3%)	32 (26.7%)	40 (33.3%)	4 (3.3%)	69 (57.5%)	35 (29.2%)	2 (1.7%)
VERY HIGH	35 (21.6%)	27 (16.7%)	33 (20.4%)	50 (30.9%)	17 (10.5%)	72 (44.4%)	32 (19.8%)	45 (27.8%)

	TOTAL	OTH	AUS,NZ	SA	SE	ASIA
18 (8.0%)	**225**	7 (3.1%)	-	10 (4.4%)	15 (6.7%)	18 (8.0%)
20 (6.4%)	**312**	4 (1.3%)	12 (3.8%)	11 (3.5%)	43 (13.8%)	20 (6.4%)
11 (9.2%)	**120**	- -	3 (2.5%)	-	-	11 (9.2%)
13 (8.0%)	**162**	-	-	-	-	13 (8.0%)

Table. Distribution of university rankings according to research types of the research papers and geographical regions where research centers/universities are located

As can be seen from the Table … medium ranked universities have the largest share of all types of research. Low ranked universities have the second place and universities with very high rankings are in third place for all research types except for “others”. Considering the number of universities in the medium and lower ranks, these results can be expected in advance.

Except for USA, CAN and OTH regions universities with medium rankings constitute the highest percentage for all of the regions. However, it is seen that approximately 28 percent of the Canadian and American universities have very high rankings.

Except for Australia and New Zealand, and other countries, low ranked universities are in the second place. It is seen that from Australia and New Zealand only medium and high ranked universities participated.

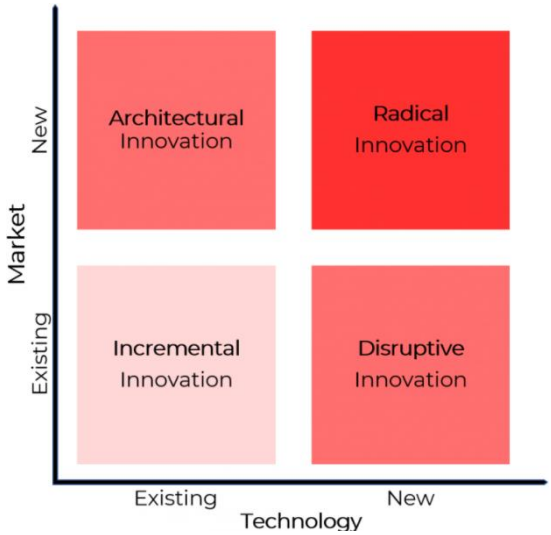
5. Conclusion & Discussion

This research work could be concluded in numerous ways as a humble effort was made to do analysis in different directions of the data extracted from ICED 2017 and ICED 2019. As mentioned above an attempt will be made to draw a conclusion from the analysis of each sub category and then a brief overall conclusion will be made from the overall research.

Starting from the dominance of NEWTOOLS and IMPLEMENTATION STUDIES as mentioned in the analysis section with ever changing dynamics of technology and paradigm shifts this category is inevitably becoming a major contributor to the design research. But at the same time, it could have some positive and negative effects on innovation as Professor Cantamessa says to every question there is not a single answer it depends on the perspective you are looking from. So, looking at the negative side dominance of these two categories could become a hurdle for radical innovation as the foundation of the design research in these categories is always a work previously done in the field, so this approach always influences in a way that the new design innovation is always relatable to the last one. And this could be seen one of the reasons for the change in researchers' behaviour after 20^{th} century as we can see there was a huge disruption in tech in terms of smart products for example Refrigerators, stoves, and microwave ovens, Personal computers, Pods and downloadable digital music, Digital photography, Cloud technology, Netflix and other streaming video services but once these inventions became innovations and started capturing markets all the attention of the industries, research institutes were towards making these products more efficient, user friendly, easy to made, smooth process for manufacturing, policies and laws. And as a matter of fact, putting it in a different perspective once these products were made more and more resources were used for incremental, architectural and disruptive innovation by the companies and researchers for a competitive advantage either in terms of cost, design, being user friendly, security, independency, etc which could be seen in the analysis as these two categories are dominating.

In order for a company to be creative, it must approach a problem from the appropriate angle. Disruptive technology has the potential to enable innovation. To be effective,

however, it must be included into a profitable business strategy. As a result, an organization's leadership must devise a clear plan for creativity and innovation while still safeguarding its fundamental operations.



In the above photo we can create a spectrum, as we move from implementation study towards experimental studies we move from radical innovation to incremental innovation but this could be contradicting when looked form a different perspective.

Moving forward to the internal analysis of **NT** and **IS** its hard to some extent to generalise because a conclusion drawn in a specific direction could contradict with another perspective so generally speaking in IS majority of authors worked towards development of a methodology as compared to early publications of ICED, which again is very constructive approach as for anything to implement a methodology is very necessary, And as far as NT is concerned it was seen that majority of the research was on either new methods or methods integrated into software which is quite a positive approach because in this era of digitalization software integration is very much needed but it could be anticipated in coming years we will see more work being done towards software integrated methods because as COVID19 has given us a new direction and as smart working has already became a main stream working style in most of the sectors.

These authors were working towards either a general need or on a specific project of a distinguished need of industry, for checking the credibility a huge part of the analysis

was based on referencing pattern in different perspective. Both positive and negatives can be drawn as conclusion from the analysis. As a positive side in ICED papers authors gave referenced to previous ICED publication the percentage was less than 40% but looking at the history of ICED it was formed in 1993 and is still in its youth it's a positive sign which shows that ICED is a well-structured publication platform for design researchers, because immense referencing to previous work creates credibility for the design research and the author and shows the originality of the paper.

Whereas looking at it from another perspective we can say it is quite dismaying when referencing pattern is seen because such a small percentage shows that the researchers specially in these two fields(NT & IS) which are specially connected to industrial needs are very much conservative when it comes to giving reference to any work which became a base for their work. We cannot question the novelty of the work but it shows that there is a lack of desire to give credit where it is due. When the situation was analysed geographically it was seen that the authors from Southern Europe comes at first, Western Europe on second central Europe third had the highest percentage of more than 30% when it comes to giving reference to previous ICED work where as USA and SA comes at fourth and other at last. But when we analyse the referencing to previous ICED we see that a huge number gave reference to either their own previous work or no reference at all which is quite disappointing and could be seen as a lack of optimistic behaviour when it comes to the collaboration of researchers.

It also shows that even in this era of technology when data gathering and measuring information on targeted variables is already an established system and is incrementally innovative, researchers don't know about the literature already available on the research work they are doing.

Moving towards the industrial involvement in NT and IS it can be concluded that these two categories didn't had much of the industrial involvement only 23% of the NT papers and 19% of the IS had industrial involvement either as direct author or as contributor. A wider perspective is that only those companies who want to have a competitive advantage at any stage of their supply chain usually get involve into these two categories. This is one of the reasons that commercial application is not present

in majority of the papers. Whereas it also shows that companies prefer to use resources for their own R&D department rather than collaborating with academia. On the other hand, companies does not want to make their research public either because they want to keep it a trade secret or until they get a patent or simply they want to have a competitive advantage over their competitors.

Another geographical analysis of the categories shows that most of the papers presented in the ICED(2017 &2019) were from Germany(1st) UK, France, USA which shows that all the factors which promote design research are favourable in these countries. As mentioned above in the analysis part that despite the fact that policies and laws related to research are more appreciative in USA comparison to EU, it could be concluded that either the trends are changing or ICED has more established name in EU than in USA. About other regions (Asia, Africa, Australia) around the world we can conclude that they still have lack of policies, resources and autonomous bodies to monitor design research.

If we look at an overall analysis of the rankling of universities almost there was an equal percentages of NT(25%) and IS(34%) from high, medium and low ranking universities which shows that ICED is a well established name and validates its credibility, which welcomes everyone to publish their novel work.

Concluding everything one can say that ICED is a well-established name in design research and this research work can become a pilot for setting standards to analyse the syntax in design research but there is still a room for improvement for the research design when it comes to referencing to other publications, as it will create inter links between different design research journals which could create an even better data base for upcoming research. On the other different regions around the world need to become more cooperative as the incremental innovation will become handy and easy if correct resources and sources are known. When it comes to Specially NT and IS more industrial involvement is needed to make the design research in these categories more vigorous and to bridge the gap between academia and industry.

Delimitations

There is no denying in the fact that covid19 has effected everyone in one way or other across the globe. And it has been a delimitation for the students working on this research work as well. Because of all the stake holders in this research were smart working from different time regions so it was some times difficult to arrange the meetings to discuss ambiguities. The research work could have been way more accurate as there is always a room for improvement if more discussion are made on a problem.

A second delimitation is human error, as it was inevitable for the participants to not get influenced by another student while making a consensus on the category of a paper where there was a difference of opinion. But all of us tried our level best to stay as much accurate as we could by having long discussions on every paper with a difference of opinion.

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