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The Future of an Industrial Engineering Technology Graduate

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Abstract

The role of University of Technology (UOT) Industrial Engineering (IE) graduates reflects the changing industry demands and will define the environment, function, and what IEs define as work. In today's economy, IE education must respond to the changing needs of industry to keep IE graduates relevant. The evolution of IE education must be congruent to the changing IE industry landscape, i.e., when educating industrial engineers, the proficiency of IE graduates to manage and implement complex systems in multidisciplinary the application of computational modeling and simulation tools.

The future of IE can be summarized by the implementation of multidisciplinary application of computational modelling and simulation tools in real-life situations. Therefore, the academic training content of industrial engineers must reflect these changes. The focus of this paper is on the future of IEs as experienced and projected by UOT's and industry. A preliminary investigation based on qualitative research suggests that stagnated IE engineering curriculum in UOTs is not responsive to industry demand and cannot provide the foundation necessary for the IE profession to remain competitive. The findings from this research will reveal the newly envisaged industrial engineer as well as the appropriate pedagogy to produce the new UOT industrial engineer who responds to industry demand.

Keywords
Technology, Engineering, globalization, 4IR, Teaching

1. Introduction
1.1 Background of the Study
Neoclassical economists brought technological progress to the forefront as an explanatory factor of economic growth. To allow for long-run growth in Gross Domestic Products (GDP) per capita, an exogenous term, labelled "technological progress" was added, which among other things was assumed to reflect advances in the use and application of technology. Advances in computing, information and communication technology have dramatically and permanently altered the landscape that constitutes what IEs call work. This landscape is not only a reality within which IEs will work but is also the reality that IEs will work with. According to (Abichandani, Sivakumar, Lobo, Iaboni, & Shekhar, 2022) this shift in the IoT (Internet of Things) paradigm has made new demands on educational institutions to train students with skills related to IoT.

The use of information technology (IT) to improve engineering education offers a lot of promise in terms of curriculum reform and the development of solutions to everyday engineering problems. According to (Hasan, Mallik, & Tsou,

2020) engineering students should be introduced to Industry 4.0 and its key technologies so that they compete successfully as highly skilled and qualified human resources besides academic success.

In the real world Industrial engineers are required to plan, design, develop, improve, transfer knowledge, implement, install and evaluate the performance of complex processes or integrated systems of people technology, and information, this means IEs must be competent in a world that will be drastically different from the one they are educated in. (Tchamdjeu, Jen, & Laseinde 2019).

Furthermore, IE problems usually manifest in systems complexity due to resource constraints, therefore the use of computing technology like industry 4.0 become indispensable (Lieu, Duc, Gleason, Hai, & Tam, 2018). Industry 4.0, also known as the fourth industrial revolution or 4IR, has brought a new way of working by increasingly improving the integration of people with complex systems through the digital world thus ending activities commonly practiced for many years by humans (Rocha, et al., 2021). If UoT continue to train IEs in these core functions without the application of high-technology enablers, it will be impossible to compete in the altered landscape in which IEs have defined as work. Therefore, IE education can no longer ignore the impact of technology on industrial engineering, as technology begets organizational culture change.

1.2 Research Question

This research questions how UOTs are preparing the competency of the future IE graduate to respond to the global demand by addressing the following questions:

- What are the requirements and demands of the global economy on the future IE?
- How should academic institutions (UoT) respond to demands for the future?
- What must be done by UoT to keep IEs competitive in the global economy?
- How should we train future IEs?

1.3 Value of the Study

This research supports current literature to emphasize the role of technology and how it impacts teaching and learning in the IE curriculum, moreover since the advancement of the 4IR (Fourth Industrial Revolution) paradigm, embracing digital transformation, fostering interdisciplinary collaboration, prioritizing adaptability and lifelong learning to enable engineering technologists to drive innovation.

1.3 Research Aims and Objectives

The Aim of the research is to conduct a literature survey to reflect on the demands for the new Industrial Engineer and how academic training can help graduates to establish the foundation necessary to ensure engineer's success in meeting the requirements and demands of the global economy in the 21st century.

2. Literature Review

The Fourth Industrial Revolution (4IR) has ushered in an era of unprecedented technological advancement, reshaping industries and societies at an exponential pace. At the forefront of this revolution are engineering technologists, whose role is pivotal in harnessing the transformative power of emerging technologies. As we navigate the complexities of the 4IR paradigm, it becomes imperative to explore how engineering technologists can adapt and thrive in this dynamic landscape. Central to the 4IR is the convergence of digital technologies, such as artificial intelligence (AI), the Internet of Things (IoT), and advanced data analytics. Engineering technologist's adept in these domains are uniquely positioned to drive innovation across various sectors (schwab 2017). The World Economic Forum emphasizes the criticality of digital skills in the future job market, highlighting the demand for engineering technologists skilled in emerging technologies (World Economic Forum 2018).

The interdisciplinary nature of the 4IR necessitates collaboration across traditional boundaries. Engineering technologists, with their blend of technical expertise and practical knowledge, serve as catalysts for cross-disciplinary innovation (Beres, 2019). Research demonstrates that diverse teams are more effective at problem-solving and innovation, underscoring the importance of interdisciplinary collaboration in navigating the complexities of the 4IR (Hong & Page, 2004). In the face of rapid technological advancement, adaptability and lifelong learning are indispensable traits for engineering technologists. Continuous professional development ensures career resilience and relevance in an ever-evolving landscape (European Commission, 2014). Studies suggest that individuals committed to lifelong learning are better equipped to navigate technological disruptions and capitalize on emerging opportunities (Boreham & Morgan 2004)

The 4IR presents fertile ground for entrepreneurial ventures and disruptive innovation. Engineering technologists, with their problem-solving skills and technical acumen, are well-suited to identify and capitalize on these opportunities (Sarasvathy, 2001). Research indicates a rising trend of engineering technologists founding startups and driving innovation across diverse industries (Hallen et al. 2014).

Amidst the technological euphoria of the 4IR, it is imperative to consider the ethical and social implications of emerging technologies. Engineering technologists play a crucial role in ensuring that technological advancements are deployed responsibly and ethically (Franssen, Lokhorst,, & Van de Poel 2012). Discussions on responsible innovation and digital ethics underscore the importance of integrating ethical considerations into technological development (Stilgoe, Owen, & Macnaghten 2013).

As we navigate the future of engineering technologists in the 4IR paradigm, embracing digital transformation, fostering interdisciplinary collaboration, prioritizing adaptability and lifelong learning, nurturing an entrepreneurial mindset, and addressing ethical and social implications are paramount. By harnessing the transformative power of emerging technologies while upholding ethical principles, engineering technologists can drive innovation and shape a sustainable future for humanity.

3. Theoretical Framework

The technology Adoption Model provides a theoretical framework to understand the factors that influence the systematic adoption and use of new technologies e.g. simulation models. As such, it is critical to develop strategies to encourage the adoption of new technologies in industrial engineering vital (Ferreira , Armellini, & De Santa-Eulalia , 2020).Therefore, the impact of computing technology on the future of industrial engineering is significant. The adoption of emerging technologies such as ICT, automation, robotics, artificial intelligence, machine learning, big data, and analytics can lead to improved efficiency, productivity, and quality. It is thus, apparent that with the rapid development of computing technology, the landscape of industrial engineering is changing rapidly.

Application of theoretical frameworks, such as Technological Determinism, Innovation Diffusion Theory, Socio-Technical Systems Theory, Human-Computer Interaction (HCI) and System Thinking in research, it becomes possible to comprehensively analyse the impact of computing technology on the future of industrial engineering. These frameworks provide a structured approach to understand the dynamics, challenges, and opportunities associated with the integration and adoption of computing technology in the field, ultimately guiding the development of strategies and policies for its successful implementation. The Technological Determinism Theory suggests that technology will drive social and cultural change, and the Innovation Diffusion Theory provides a framework for understanding the adoption of new technologies, therefore adoption of a theoretical framework is indispensable.

The theoretical landscape in the technology and pedagogy arena is dominated by theories dating from the 1960s and although the debate about the role of technology in education is not yet fully exhausted to respond to 4IR, sustainability and employability requirements. These require contextual engineering programs, to help students develop skills in cross-disciplinarity problems. Therefore, engineering students should be able to understand the needs for technological, sustainable solutions in context. The engineering graduates should therefore be able to act in complex situations. The question is how UOTs are responding now and in future (Hadgraft & Kalmos 2020).

To assist in the design procedure for IE's, major advancements has been noted e.g. Systematic modelling, effective programming styles, predictive maintenance, and augmented reality (AR). These technologies provide people with an interface to interact with the digital world. Research review indicates that the context of research concerning AR gets increasingly broader, especially by addressing challenges when implementing AR solutions (Egger & Masood, 2020). The emergence of AR is accepted but still not adopted by UOT's in South Africa.

4. Data Collection

This research is a desk-top study that applies qualitative data collection methods. Yin (1994) and Patton (2002) stipulate that a hallmark for case study research is the use of multiple data sources, a strategy which also enhances data credibility. This case study will apply the following triangulation of data sources i) document analysis; ii) archival records and iii) field notes. It is rational to apply document analysis in this research since it is often used in combination with other qualitative research methods as a means of triangulation, i.e., the combination of methods in the study of the same phenomenon to enable a researcher to draw upon multiple sources of evidence and, to seek convergence and corroboration of the research results using different data sources.

Rossman and Wilson (1985), in their study of evaluating regional education service agencies, designed document reviews to identify the mission of agencies as described in documents and reports. Sogunro (1997) provided an exemplary clarity concerning the use of document analysis, he reported that the use of document analysis provided information on history, goals, objectives and substantive content of the phenomenon under study. Stake (1995) and Yin (1994) found that document analysis is particularly applicable in qualitative research for intensive studies producing rich descriptions of a single phenomenon. Patton (2002) stipulates that field notes are rich, detailed descriptions, including the context within which the observations were made, and they consist of activities, behaviours, actions, conversations, interpersonal interactions, organizational or community process, or any other aspect of documented human experience in the field.

The rational to applying field notes is supported by Patton (2002) reflections that field notes are applied in qualitative research to understand the true perspective of the subject being studied and that they allow the researcher to access the subject and record what they observe in an unobtrusive and nonreactive manner. The research requires an in-depth understanding of researcher's experiences and observations while participating in an intense and involved manner, thus field notes will be applied as data source in this research. The decision to gather and analyse archival records is linked to the research propositions developed in the conceptual framework of this study.

The use of archival data is supported by the claim that archival data is an increasingly viable resource because of an ever-greater amount of archival verbal and visual material has become universally available with the information proliferation attributes of the internet. Archival data comprises of wide array of empirical data created by researchers for their personal use or on behalf of an organization. Contents of an archive that is applicable in this research consist of various material (e.g. letters and diaries; weblogs and discussion list posting; press releases and reports; magazine articles and rating websites; etc). Archival data will be used to develop an understanding of the research context and where applicable to inform the development of concepts and theories.

5. Results and Discussion

It is evident that the practice of IE needs to change further because of the demands for technologies and products that exceed the existing knowledge base and because of the changed professional environment in which IEs need to operate. This change must be encouraged and facilitated by changing engineering education curriculum. It is also apparent that there is a gap in existence between the theory on how IEs should be trained, based on the changing global trends and the impact of technology on IEs work and the working environment, when compared to the current IE curriculum in the UoT. The gap is so wide it is as if IEs training in the UoTs are prepared for a totally different environment than the current high-technology setting and worse so, not to mention the future environment that will constitute the work of an IE.

This gap also manifest in the literature survey in that less research output is published on the impact of technology on IE, partly because thousands of comparisons of scenarios of computing and noncompeting pedagogy have been made since the 1960s (Tamim et al. 2011), (Hadgraft & Kalmos 2020). To this effect, it is not surprising that studies and research for the past 20 years and more have been meta-analyzed at intervals in an attempt to characterize the effects of new computer technologies as they emerge, No wonder more than 60 meta-analyses have appeared in literature since 1980, each focused on a specific question that is meant to address the different aspects of the impact of technology, such as the type of technology It needless to indicate that although research studies comparing various forms technologies in use in both control and treatment groups are becoming popular, it does not mean that technology versus no technology comparisons will become obsolete (Hadgraft & Kalmos 2020).

Technology tools are fun to discuss, but the bottom line is they impact on industrial engineers. It is evident how these tools may affect working lives of IEs, and much of the change is experienced already. But how will it affect the actual work IEs do? For example, how will work be measured in this new environment? There may be employees who have no need to be on site. Through e-mail, cellular communications, wireless computing, groupware, video conferencing and tele-presence, a virtual setting is possible. Benefits abound are reduced facility cost, reduced travel expenses, less pollution, more flexible time for employees, ability to handle special needs (e.g., working mothers, handicapped), and drawing skills from people around the world or from people whose skills otherwise may not be utilized.

For those organizations which have industrial engineering staffs, there are several problems confronting the I.E. involvement in information systems development, and these are, the in-house staffs are usually overburdened with routine activities which are, for the most part, comprised of traditional I.E. functions and can therefore not participate in other activities without increasing the size of the staff. Literature review suggests that I.E has paradoxically neglected the management and operation of computers. The I.E. staff and the computer centre are usually in different divisions and computer centre management is simply unaware of the potential application of industrial engineering. Once the I.E. staff recognizes their role in information systems and overcomes their reluctance, the other problem areas can be overcome by selling themselves and what they can do to increase productivity in a computer-based environment.

It is evident that the working domain of IE is certainly not limited to the traditional areas of application such as manufacturing. It is apparent that the skills and techniques of industrial engineering are applicable to improving the information systems development process and computer centre operations. Therefore, it is a challenge to educators and students of industrial engineering, as well as practicing I.E.'s, to take advantage of this opportunity to play a significant role in the field of information systems.

Evidence to support a technology enhanced pedagogy for IE is found on the Engineering Council of South Africa (ECSA) 2014 review comments for the IE departments in UoTs. In the closing comments it was highlighted that the level of technology application is unsatisfactorily low and IE pedagogy in the universities does not reflect the demands of the working world in the 21st century. This comment support postulates of (Dlamini & Nkambule, 2018) that with new ways of learning and teaching in a complex digital environment, digital technologies are widely seen as enhancing teaching and learning, thus fueling their rapid adoption and integration and has resulted in the pursuit of alternative pedagogical approaches throughout developed and developing societies.

ECSA’s declarations are concomitant to the declarations made by Davenport & Short (1990), that IEs aspiring to improve the work environment must apply the capabilities of information technology. And IE techniques and tools such as BPR and information technology are natural partners (Teko, 2024). The impact of technology on IE has been touted for more than a decade, yet industrial engineering has never fully exploited the relationship between technology and IE applications following a realization of the mismatch of engineering skills produced by universities and those that industry required (Nyemba, Mbohwa, & Carter 2021). ECSA in its recommendation to Unisa’s IE department is clearly in congruence with Koelling et al. (1996) that indeed, it is certain that IE requires the expertise in computer technologies, since technology impacts IE currently and in the future. Therefore, it is mission critical for IE profession to evolve and embrace the changes in the global work arena and in technology.

The evidence of this transformation in the work arena manifest through a phenomenon that clearly shows that the IE profession is in danger of losing its identity because other professions are encroaching on the IE traditional areas. It was Long (1976) who postulated, that an IE with a basic knowledge of information systems and computers is qualified to succeed in the future, yet in almost four decades academic institutions (UoTs) have not heard the call to transform the IE curriculum to meet the demands of the future working environment.

The fact that academic institutions (i.e. UoTs in this case) have not yet recognized the transformative potential of information systems technologies in IE, is still a deficiency of many UoT today, as it was in 60s and 70s, as was declared by Long (1976) then and ECSA in 2004.

The IE does not have to be skilled as e.g. data processing professional, but for IEs to feel more confident and experience great success in the high-technology environment, IEs must be presented with a substantial body of knowledge in system development processes, hardware and system software technology (Long’ 1976 & Davenport & Short, 2003).

An industrial engineering qualification will become obsolete, like any other product in the market, if there are no innovative interventions to keep the qualification current and relevant. Development in computing technology provides a great opportunity for innovation with regards to the curriculum and the content of various modules, in the qualification. Computing technology provides an opportunity to transform the delivery mode as per the institutions strategic plan. Fig.1 below (adapted from Rink and Swan 1979) depict a typical product life cycle and the design attributes commensurate, for continuous improvement of the product or qualification innovation interventions these play a vital role.

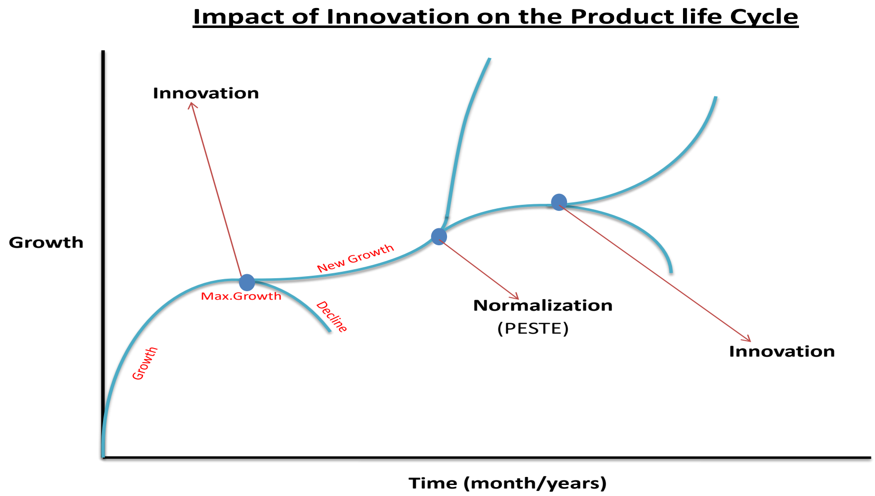

Figure 1. Product life cycle for continuous improvement of a qualification innovation (Rink & Swan)

The product life cycle in Fig.1 depicts an initial growth stage and a maximum growth point is reached, and the product demand starts to decline. Marketing theory and Practice indicates that, if innovation is applied as soon as the product life begins to decline, then a new growth stage will emerge. Unless constant innovation is injected, as the product life begins to decline, the product will cease to grow and ultimately become obsolete. In terms of terms of Industrial engineering the decline position means that the qualification will be outdated and irrelevant. And therefore, the Industrial engineering graduate will not be equipped to face the complex challenges in the industry.

5.1. Educating Industrial Engineers for the future work Arena

As the computer has become an indispensable tool of all professional and business activities, it has become an inalienable component of industrial engineering education. From the age of keypunching computer cards (so called IBM cards) in the 60s to the age of portable laptop computers in the 90s, the mode of computer use has changed drastically. Has the mode of industrial engineering education changed drastically too? The majority of the industrial engineering courses contain a feature of using computers which may be either the mainframe or personal microcomputers. The degree of use may vary depending on the nature of the course.

It seems certain that the percentage of computer usage will increase every year. We have witnessed that an increasing number of textbooks that include software packages. Numerous institutions have tried to incorporate the use of computers in their courses by developing more programs suitable for the courses and by selecting textbooks that have computer software packages. It will be an understatement to say, by 2015, one hundred percent of industrial engineering courses will use computers. Many students have their own computers and their own software packages and know how to use the whole Microsoft package suit, why don't we execute teaching and learning in a "cloud", because willing or not, cloud computing is the future.

Many students have their own computers and their own software packages and know how to use spread sheet packages and word processors even though these are not offered in a regular course in the College of Science and Engineering. This means that they are trying to use and learn more about computers. This trend will increase and will accelerate rapidly when we offer courses that require more computer use. Although the percentage of students who own computers is still low in the university, the percentage will increase. When that happens, we can teach the materials more effectively and can teach more complex problems in the class and can give examinations that require the use of the computer. More importantly, it seems that increased use of computers may result in a better industrial engineering education. It is rather apparent that in the curriculum for Industrial Engineering education, there needs to be a module on application of computers for IEs. This module must focus on imparting computing skills to undergraduate Industrial

Engineering students and create a platform and foundation for other modules to use computer application as a method for teaching and learning.

Terry Anderson, in his book: Theory and Practice of on- line learning, indicates that the level of integration of technology and the extend of transformation varies from module to module, depending on elements of the education technology stack of the institution. This means various modules will achieve different integration and transformation levels as per the institutional functional strategy. Typically, a grid for integration and transformation of modules would indicate a position of a particular module in a range between on-line and off-line, and between contact base and remote/distance. The complexity of this transformation and integration process is intensified by the need for the convener of the migration project, to be in full comprehension of the curriculum strategic environment and the module content deliverables, as per the Anderson's model of interaction in Table.1.

Table 1. Anderson's Model of interaction

THEN	NOW	FUTURE
F2F	INTRANETS	KNOWLEDGE
TEACHING	E-LEARNING	VLE
DISTANCE EDUCATION	EXTRANETS	NETWORKS

According to Anderson, the migration of each module happens in a context where the is a full comprehension of the education technology stack (Fig.2) and the institutional operations plan, understanding strategic environment dynamics and the envisaged deliverable of the curriculum. The grid in Fig.2 below depicts various position for different modules as will be determined by the ease of integration and transformation of the module content.

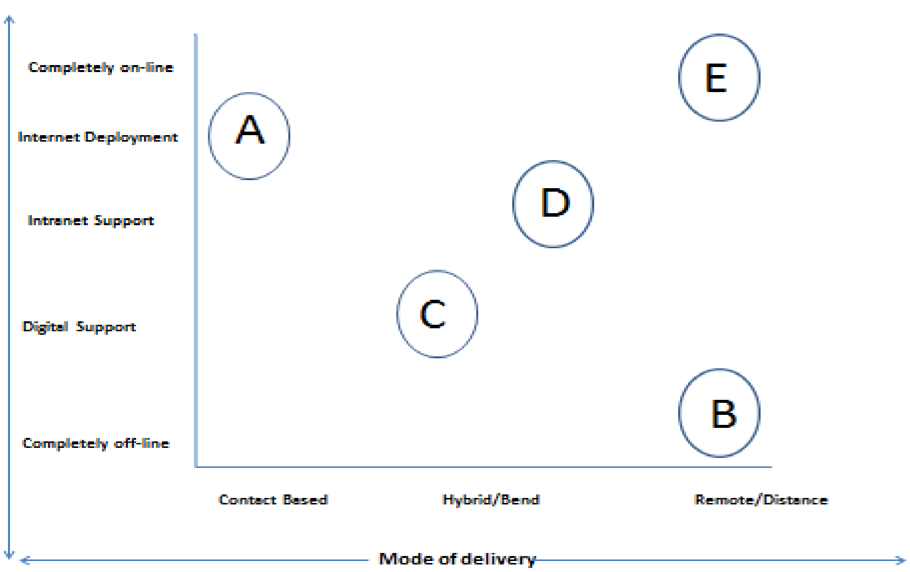

Figure 2. Transformation progression grid (Adapted from Anderson's Model of interaction)

6. Conclusion

The industrial Engineer, in the near future, will be required to design and implement management, control and visibility systems necessary to achieve optimization. Many information systems provide visibility; some provide control and enable management, but rarely does one provide optimization at all levels of the organization (synergy).

Yet, optimization can be achieved by incorporating the industrial engineering tools of operations research and management information systems (MIS). To develop an applicable information systems environment, adequate consideration must be given to the analysis and design of the requirements of synergistic optimization.
The systems approach, with which the IE is so well acquainted, calls for detailed analysis, planned design, and total management and therefore, provides a means for a structured development of MIS. It therefore a logical conclusion to state that it is a duty of all academic staff in IE to ensure that all modules are on-line, that Open Distance Learning (ODL) platforms for teaching and learning are explored and implemented, and that we navigate towards teaching in a cloud computing environment. All this begins with the realization and embracing the impact of technology and specifically computers on the future of Industrial Engineering.

7. Recommendations

The research on the future of engineering technologists within the framework of the 4IR makes a significant contribution to the extension of the body of knowledge in several key ways. Firstly, it offers insights into the evolving role of engineering technologists in a rapidly changing technological landscape, shedding light on the skills, competencies, and adaptability required to thrive in the 4IR paradigm. Secondly, the research identifies emerging trends and technologies that are shaping the field, providing valuable guidance for educational institutions, policymakers, and industry stakeholders in preparing for future workforce needs. Moreover, by exploring the challenges and opportunities presented by the integration of automation, artificial intelligence, and other disruptive technologies, the study contributes to a deeper understanding of the socio-economic implications of technological advancements on engineering technologists and society at large. Overall, this research enriches the existing body of knowledge by offering actionable insights and strategic recommendations for ensuring the continued relevance and effectiveness of engineering technologists in the era of the Fourth Industrial Revolution.

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