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Toward the Adoption of Industry 4.0: The Skills of the Civil Engineering Workforce Relevant to the Fourth Industrial Revolution

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Abstract
There is no doubt that the pace of innovation is changing with the advent of new technologies related to the fourth industrial revolution (Industry 4.0). The transition from the current to the future for these continuous changes in technology considerably changed the nature of jobs affecting people's skills that are needed in the transformation to create an organization capable of continuous change. Therefore, this paper intends to assist industries in determining which skills are likely to become focal points in the adoption of Industry 4.0 to provide suitable suggestions for planning the next course of action on best practices of technology adoption for civil engineering industries. Since Industry 4.0 is reshaping the workforce's skills, this study is conducted to fill this research gap by analyzing the skills of the civil engineering workforce relevant to the fourth industrial revolution, whereby the demand for special skills will drive the shift toward technology adoption. The research method administered is a qualitative method, in which the interview was based on a focused group discussion of nine members from Malaysia's civil engineering industries. The findings of the data collected provide three main groups requiring different skills which are low-skilled workforce (technical skills, basic communication skills, safety skills team Working skills), semi-skilled workforce (machinery knowledge and skills, communication skills, leadership skills, and health and safety skills), and high-skilled workforce (engineering skills, organizational skills, decision-making skills, and problem-solving skills). Interestingly, the paper introduces emerging skills (digital drawing, instrumentation skills, risk management skills, remote worksites, and mobile access, environmental skills/schedule waste management skills, and autonomous robots skill) demanded for the adoption of Industry 4.0. The findings could help support and guide best practices of technology adoption for civil engineering industries. Future research might be helpful to further add skills for the sustainability of Industry 4.0
Keywords: Industry 4.0, Skills, Competencies, Civil Engineering, Workforce, Technology Adoption.

Introduction

In the early stages of Industry 4.0 implementation in Malaysia, the government has dedicated itself to moving away from reliance on low-skilled employees, notably in the manufacturing

sector. Adopting new technologies to make businesses more efficient and productive will follow global trends. As a result of the arrangements, low-skilled labor is unsustainable in the long run and prone to human errors, lowering the quality of the items produced. In this type of business, implementing Industry 4.0 will boost efficiency and encourage zero-defect outputs. The nature of the industry in civil engineering construction differs from that of manufacturing. Although automation has increased the number of construction jobs, it has also opened up new opportunities and boosted the demand for new skills. Another shift in the labor market is on the horizon as construction enters the fourth wave of technological advancement: the introduction of new digital industrial technologies collectively known as the Fourth Industrial Revolution.

Human factors are important in the face of increasingly rapid changes in technology, products, and systems. The fourth revolution is considered fundamentally different from the previous three because of its technology, which combines the physical, digital, and biological worlds and has an impact on all fields and industries, therefore, employees need to know about the current revolution and undertake processes to continually enhance quality and quantity efficiency (Benesova and Tupa, 2017). The future of these continuous changes in technology is affecting the management and business process, driving the organization not only to focus on digital enhancement and reengineering of products but also on people's skills, knowledge and innovation. The truth is that many of the most common positions in Industry 4.0 were still not in existence 10 years earlier (including app designers, computer clouds, information researchers, drone and driverless car technicians, and others) (Whysall et al, 2019). Because of that, the main challenge that managers will have to face in the next decade is to understand and cope with the evolving setting that is fast-changing and to react by changing and implementing the organizations accordingly (Shamim et al., 2016). The challenge of competency for the fourth industrial revolution is different from any previous organizational change (Whysall et al., 2019). The main characteristic of important staff and organization as a whole is their distinct competencies, whereby there is an increasing need for new skills (Sharma et al., 2022). Therefore, Industry 4.0 changed the nature of jobs requiring various skills. This paper aims to fill this research gap in terms of Industry 4.0 adoption. Because of that, the organization cannot proceed to develop or survive unless there is skills development (Itika, 2011). Therefore, this study is conducted to identify skills related to Industry 4.0 in the civil engineering industry.

Literature Review

Organizational Restructure

The challenge of industry 4.0 is to restructure jobs since some of the less demanding tasks will disappear rapidly and other jobs will appear (Olsson and Xu, 2018). This episodic organizational transformation involved the restructuring and downsizing number of employees (Olsson and Xu, 2018). When decreasing the workforce, the number of tasks to be performed within the organizational network remains initially constant, but fewer people are available to perform the tasks (Sivathanu and Pillaia, 2018). Thus far, previous studies have suggested that the change of Industry 4.0 leads to job losses if employees cannot adapt and meet new demands rapidly enough (Birkel et al., 2019). The idea of industry 4.0, on the one side, requires employees to be released from manufacturing, service, and support procedures in which new technologies, robots, and automated leadership structures are to be substituted (Olsson and Xu, 2018). On the other side, firms are unsure about the shortages of employees with the necessary qualifying structure and new skills in the implementation of the

components of industry 4.0 (Sharma et al., 2022; Macurova et al., 2017). For this reason, restructuring and downsizing of corporation activities are some of the most difficult problems faced by organizations and their staff (Olsson and Xu, 2018).

The ability to react rapidly to revolutionary processes is a consistent theme in contemporary literature (Sivathanu and Pillaia, 2018). On one hand, high-technology industries are constantly concentrated on the need to design complicated structural settings that allow them to operate efficiently in hyper-competitive settings (Carbery and Garavan, 2005). On the other hand, Sivathanu and Pillaia (2018) suggest that a flat, flexible organizational structure based on the hierarchy will generate a conducive atmosphere for Industry 4.0 (Sivathanu and Pillaia, 2018). A flat hierarchy would decrease levels of communication and accelerate decision-making. However, the value-generating impacts organizations of Industry 4.0 technological change resulting in both negative and positive impacts on organizational restructuring. Noting that, the organizational structure should be customized to the demands of Industry 4.0 in order to transform an organization effectively. The organization is at risk of both sticking to the current organizational structure and too radically transforming the current organizational structure (Birkel et al., 2019). Furthermore, traditional companies require greater flexibility in their organizational structures because traditional R&D teams are not able to develop company models or software but instead require new, more flexible teams (Birkel et al., 2019).

The challenge in these elements for Industry 4.0 is the responsibility of human resources. Employment in Industry 4.0 should be based on a variety of skills and heterogeneous knowledge, which should be tested before selecting the candidate in the screening process of downsizing (Chang and Yeh, 2018). Organizations should use extensive recruitment and selection procedures to select the right candidate for each job (Ma Prieto and Pilar, 2014). For example, recruiting innovative employees should focus on identifying the attributes required for innovative behavior, such as openness to experience, which can be evaluated in the selection process by psychometric testing. Active imagination, inner sensitivity, variety of preferences, intellectual curiosity, creativity, and flexible thinking characterize openness to new experiences (Shamim et al., 2017). In addition, people who are generally open to new experiences show a more positive attitude to learning. In the recruitment and selection process, organizations should also assess the candidate's objective orientation, which can be oriented toward learning and performance. However, the role of a functional expert is to fully understand, redesign jobs required, and hire talented people according to the functions and jobs required.

Skills and Competencies

The employees expect a shift in the skills required for companies in the future (Birkel et al., 2019). This especially impacts those operations that can be automated in relation to roles undertaken by low-skilled staff, such as repetitive tasks, it also affects the role of planning and decision-making, it must be observed here that low and more-skilled staff are in danger of loss of their jobs (Birkel et al., 2019). The knowledge and development of staff skills is an important conditions for the success of an organization in today's competitive setting (Shamim et al., 2016). In specific, IT-related abilities, interdisciplinary thinking, and action, will be required in the future. However, many people interviewed by Birkel and colleagues (2019) say that not only IT employees are useful but also employees who can communicate with each other through the traditional key enterprises of the companies (Birkel et al. 2019). Whysall et al (2019) agree that industry 4.0 requires individuals who are intellectually

enthusiastic about their job, who reflect constantly on their experience, who operate with peers, and who use their intelligence and effort to add to the growth of knowledge, skills, and experience-based changing concepts (Whysall et al., 2019). Employees with work specialization are less relevant than staff who have multifunctional skills and abilities (Piccarozzi et al., 2018).

To develop an employee to satisfy current and future market requirements, it is necessary to identify the necessary competencies (Whysall et al., 2019). Competencies are described as the collection of skills, abilities, knowledge, attitudes, and motives that a person needs to efficiently cope with jobs and challenges (Hecklau et al., 2016). According to Hecklau and colleagues (2016), four primary classifications for competencies to industry 4.0 are identified. First, technical competency contains all the knowledge and skills of the workplace, while secondly, all the skills and abilities for identifying and creating decisions generally cover methodological competencies. Third, social skills and abilities for collaboration and communication approaches are included in social competency. Finally, personal competency includes the principles, motivations, and behaviors of an individual (Hecklau et al., 2016). In regard to competencies, the accessibility and collaboration components of data throughout the value chain promote the move to Industry 4.0. Therefore, the results by Whysall et al (2019) indicate that an efficient engineer today needs new thinking and know-how, a wider range of skills that go beyond technical knowledge (Whysall et al., 2019).

Because of technological advances such as cloud computing and mobile-first, organizations face massive reskilling challenges in order to remain relevant and competitive. Recognizing the scarcity of in-demand skills and the value of institutional knowledge in their existing workforce, according to Spagnoletto et al (2019), organizations set out to retain and reskill existing employees for newly created roles, fostering a culture of perpetual learning and increasing mobility within the company (Spagnoletto et al., 2019).

Workforce Development

Workforce learning and development are important challenges to industry 4.0 (Whysall et al., 2019; Liboni et al., 2019; Benesova and Tupa, 2017; Shamim et al., 2017; Shamim et al., 2016) because skills and talent development for the fourth industrial revolution is different from any previous organizational change (Whysall et al, 2019). The abilities needed to perform the tasks of Industry 4.0, therefore, do not yet occur within or at least not in adequate volume within the learning or skill scheme (Whysall et al., 2019). It is very essential to provide a climate of creativity and learning to make staff operate on a level with the requirements of Industry 4.0 since it is a significant facilitator of learning and innovative behaviours at work (Liboni et al., 2019). Industry 4.0 success depends on the company's ability to innovate (Lasi et al., 2014), whenever a company intends to be smart, they need intelligent employees and a learning and innovation climate that requires appropriate management practices. Industry 4.0 requires the development of organizational capabilities in different dimensions (Shamim et al., 2017).

The industries are dedicated to learning significance and communicate obviously that learning is essential to achieve organizational success (Benesova and Tupa, 2017). The research by Shamim and colleagues (2017) believed that innovativeness, knowledge, and learning have the potential for the effective application of Industry 4.0 (Shamim et al., 2017). Over the last century, businesses have been tending to meet changing resource requirements quickly with the help of ready-made competing talent to meet instant job requirements (Whysall et al.,

2019). Therefore, Industry 4.0 of an organization is in challenge to prepare a workforce to be able to meet the changed requirements to survive the new revolution (Birkel et al., 2019).

Civil Engineering in Malaysia

The industries in Malaysia have been called upon to move towards higher value-added processes, digitization, advanced technology, and effective resource use in order to drive competitiveness forward (MITI, 2018), however, Malaysia's Construction Industry is one of the driving forces of Malaysia's economy (Razak et al. 2010). Malaysia has the objective to transform its sectors into industry 4.0 according to the Ministry of International Trade and Industry (MITI, 2018). Civil engineering industries are adapting to the new era impacting the sectors including energy efficiency/ renewable energy/minimization of energy, water efficiency materials efficiency/recyclable and recycled products, and waste reduction (Ba Qatyan and Rahim, 2023) .

Construction is divided into three categories in the Malaysian Standard Industrial Classification 2008 (MSIC, 2008): building construction, civil engineering, and specialized construction activities. This study is mainly concerned with Civil Engineering. It includes new construction, repairs, additions, and alterations, as well as prefabricated structure installation on-site and temporary construction. Heavy constructions such as highways, streets, bridges, tunnels, trains, airfields, harbors, other water projects, irrigation systems, sewerage systems, industrial facilities, pipelines, electric lines, and outdoor recreation facilities are all classified as heavy constructions by MSIC. Civil engineering consists of three groups (1) Construction of roads and railways (2) Construction of utility projects and (3) Construction of other civil engineering projects.

Methodology

Study Design

A qualitative method of research design is utilized in this study. The qualitative approach is used to collect diverse data to achieve the research objective. The purpose of the study was achieved through Focused Group Discussion (FGD), where respondents were industry experts and practitioners. Qualitative data collection is the best method for the phenomenon understanding (Rosaline, 2008). However, qualitative research is "a systematic, subjective approach to describe and interpret life experiences, often in the words of selected individuals, and give them meaning" (Saunders et al., 2009). Qualitative research allows researchers to explore behaviours, attitudes, perspectives, feelings, and experiences in-depth, quality, and complexity of a situation through a holistic framework, value systems, concerns, motivations, aspirations, culture, or lifestyles (Ereaut, 2011).

A data collection instrument refers to "the device used to collect data, such as a questionnaire, test, structured interview schedules and checklists" (Saunders et al. 2009). The main instrument used is one round of open-ended, semi-structured, in-depth interviews.

Participants

In order to obtain further information about demand skills, FGD was administered with different practitioners' positions investigated as presented in table 1. As mentioned, data were collected using qualitative methods, in this section, the results of the FGDs are presented using thematic analysis.

Table 1

Demographic profile information of participants

NO.	GENDER	POSITION	WORKING EXPERIENCE
1	Female	Civil Engineer	>5 years
2	Male	Managing Director	>5 years
3	Male	Civil engineering	>5 years
4	Male	Senior Manager	>5 years
5	Male	Civil engineering	>5 years
6	Male	project engineer	>5 years
7	Male	Senior Manager	>5 years
8	Male	Project Management	>5 years
9	Male	Special Officer & Strategy Management	>5 years

Nine industry experts were selected for the FGD, which is managed by a facilitator to foster interaction among the members while keeping the discussion under control. In terms of industry experts, they must have at least five years of experience in the linked field. The results of the FGD debate are recorded, transcribed, and analyzed by the researcher.

Procedure

In order to carry out good research, the researcher must have the overall view of the process for each step of the study that is planned systematically. The research procedure of this study is a qualitative approach, depicted in Figure 1. Details elaboration of phases in the data collection procedure is subjected to six phases:

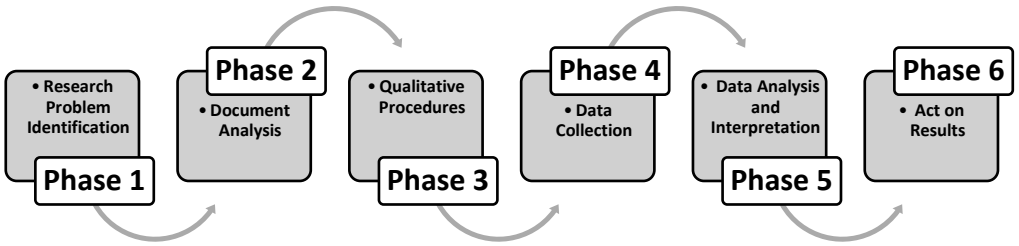

Figure 1: Data Collection Procedure

Phase 1: Research Problem Identification

The initial stage is to identify concerns and/or data gathering possibilities, and then decide what to do next. To do this, conducting internal and external assessments to understand what is going on inside and outside the organization may be effective.

Phase 2: Document Analysis

The second phase is to collect secondary data by reviewing publicly available published information from sources such as websites, archives, and other written reports.

Phase 3: Qualitative Procedures

The qualitative measures acquired from pre-existing or official data that has previously been documented or developed by the organization throughout its ordinary activities make up the third step. Interviews are documented in a variety of ways during the FGDs to gather information offered verbally by industries, including written notes, audio recordings, and video recordings from nine participants.

Phase 4: Data Collection
The fourth phase entails being aware of practical considerations and best practices for dealing with logistical issues that arise frequently throughout this phase. Attention is given to the process of data collection to ensure its reliability and validity before the next phase is begun.

Phase 5: Data Analysis and Interpretation
The fifth phase is to analyze and interpret the data collected. Depending on the methodology employed, and qualitative data obtained, the analysis can be complex or simple.

Phase 6: Act on Results
The sixth phase is to act on the data, and provide a solid basis for creating an effective action plan designed to achieve the objective of the study.

Results
The qualitative research method is utilized in order to investigate the view of skills in demand. The reason behind this aim is the potential of industries that are supposed to lead and undertake towards contributing to the adoption of Industry 4.0.
Thematic Analysis is the most common qualitative method of data analysis and is used here to analyze the data gathered from FGD. It was emphasized that the skills are divided into four clusters. The first group is a low-skilled workforce, the second group is meant for a semi-skilled workforce and the third group is a highly-skilled workforce. Interestingly, the article introduces emerging skills for the adoption of Industry 4.0

Table 2
Skills in Demand of low-skilled workforce

WORK LEVEL	SKILL	DESCRIPTION
Low-skilled Workforce	Technical skills	The abilities and knowledge needed to perform specific tasks.
	Basic Communication Skill	Speaking, listening, and reading capabilities.
	Safety Skill	Avoiding situations that may cause harm to themself or others, fire safety skills, and knowledge of site signs.
	Team Working Skill	Understood as the willingness of a group of tasks to work together to achieve a task aim.

As presented in the analysis in table 2 above is showing the skills of the low-skilled workforce. From the FGD, members raised the skills with its descriptions as shown in the table. The skills include technical skills, basic communication skills, safety skills, and team working skills.
Table 3

Skills in Demand of semi-skilled workforce

WORK LEVEL	**SKILL**	**DESCRIPTION**
Semi-skilled Workforce	Machinery knowledge & skill	Skills and Knowledge for the use and maintenance of machinery on construction sites.
	Communication Skill	Speaking, writing, listening, reading, and presenting ideas to make a lasting impression on the project team.
	Leadership Skill	Motivating team members and low-skilled workers, inspiring them, and fostering enthusiasm for projects.
	Health and Safety skill	Avoiding situations that may cause harm to themself or others, "stranger awareness," fire safety skills, and knowledge of project signs.

As outlined in above table 3, the semi-skilled workforce in the CEI requires four main skills. The skills addressed by the group members during the FGD were machinery knowledge & skills, this is focusing on the skills and knowledge for the use and maintenance of machinery the on construction site. The participants added communication skill is demanded to speak, write, listen, read and present ideas to make a lasting impression on a project team. leadership skills are demanded by motivating team members and the low-skilled workforce, inspiring them, and fostering enthusiasm for projects. As well as health and safety skills to avoid situations that may cause harm to themselves or others, "stranger awareness," fire safety skills, and knowledge of project signs.

Table 4
Skills in Demand of skilled workforce

WORK LEVEL	SKILL	DESCRIPTION
Skilled Workforce	Engineering Skill	Should be good at construction method, maths, physic and understand the importance of following the data when making design decisions
	Organizational Skill	Ability to be systematic, efficient, and demonstrated by planning your time, quality, and cost of the project effectively
	Decision-Making Skill	Demonstrate your ability to choose between two or more options by processing all relevant information and speaking with the appropriate points of contact in a given situation.
	Problem-Solving Skill	Help to determine why an issue is happening and how to resolve that issue.

The findings and their results are presented above in table 4 on skills in demand for a skilled workforce and its description gathered from the session of FGD. Presented high level of skills including engineering skills, organizational skills, decision-making skills, problem-solving skills, digital skills, writing, and reporting skills.

The results from the focused group discussion with regards to skills demanded by the workforce clustered into four, the first three clusters were according to the work level. The first level focused on the low-skilled workforce followed by the semi-skilled workforce and the third level is a skilled workforce. The skills required by each level were different. This is because of the nature of their job level and job description.

Table 5
Emerging Skills for Industry 4.0 adoption

Emerging Skills
Digital drawing (digital skills, cloud computing, internet of things)
Instrumentation skill
Risk management skill
Remote worksites and mobile access
Environmental skills/schedule waste management skills
Autonomous robots skill

From the session of FGD, the skills to the adoption of Industry 4.0 are not limited to existing skills. There are emerging skills that are demanded by the civil engineering industry workforce shown in table 5. Six emerging skills were elaborated on during the session. The skills are digital drawing, instrumentation skills, risk management skills, remote worksites and mobile access, environmental skill/schedule waste management skills, and autonomous robots skill

Discussion

It was agreed that when it comes to responses to the global megatrends, Malaysia is now at a critical inflection point (Talent Corp Malaysia visioning, 2017) because there is still demand for enhanced skills; that require a certain level of knowledge for the use of new technologies. The current study found that there is a variety of skills demanded for the adoption of Industry 4.0 technologies. The results were clustered in four clusters of low-skilled, semi-skilled, and skilled workforce toward the adoption of Industry 4.0. Moreover, emerging skills for adoption are required by a semi-skilled and skilled workforce.

To adopt Industry 4.0 concept, employees are more disposed to improve their skills since they attribute great importance to these new competencies in their jobs. New competencies for engineers and construction consultants clearly gave the meaning of learning and development for future engineering (Whysall et al., 2019). There is a need for a more efficient skill plan which ultimately enhances organizational innovativeness and employee innovative work behaviour as well.

The reasons behind the required skills are that Industry 4.0 drives to paperless, government requirements for Building Information Modelling (BIM), accessibility, and ease to share information. Concerns were expressed about these skills arising for on-site troubleshooting and minor modification on-site. There were some suggestions on emerging skills for the motive to manage quality problems, manage costing problems, and manage timing problems. Further analysis is caused by the rise of codes and wireless systems including CCTV, Barcode, RFID, and QR Code. What is interesting about the data is that emerging skills are required to reach the goals of the government and the Department of Environment (DOE).

It was decided that all work skill levels in civil engineering construction should have comprehensive capabilities; this is a determinant of a construction personnel's success. To ensure that civil engineering construction professionals are professionally suited for the

construction business, they should have both hard (technical) and soft (behavioural) competencies. It's a 'must' because they are at the vanguard of their field, where a lot of duties are on the line in today's fast-paced construction environment.

Conclusion

Evolving technologies and skills generated by the fourth industrial revolution provide a perfect storm for Industry 4.0 adoption. Industry 4.0 consideration is to enhance skills and competencies, learning and development, creativity, and adoption of innovations they have to build their strategy accordingly. This study used a qualitative method for data collection. The study findings were based on four clusters which are low-skilled workforce, semi-skilled workforce, and skilled workforce, these clusters were based on a work level. The fourth cluster is emerging skills that are required for the adoption of Industry 4.0. The skills demanded by the low-skilled workforce are technical, basic communication skills, safety skills, and team working skills. Besides that, a semi-skilled workforce demands the skills of machinery knowledge & skills, communication skills, leadership skills, and health and safety skills. on top of that, engineering skills, organizational skills, decision-making skills, problem-solving skills, digital skills, and writing and reporting skills are the demanded skills for the skilled workforce. The emerging skills are digital drawing, instrumentation skills, risk management skills, remote worksites and mobile access, environmental skills/schedule waste management skills, and autonomous robots skill. These are the skills examined for the civil engineering workforce's highly demanded skills. Taking both the findings of this study and its limitations into account, some recommendation for future research is made. Firstly, this article focuses on the skills for technology adoption. Further research is required to investigate the process of Industry 4.0 adoption. Secondly, the current paper focuses on the adoption of industry 4.0, it can be stated that it might be helpful to further add elements for the sustainability of Industry 4.0. The findings could help support and guide best practices of technology adoption for civil engineering industries.

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