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Future Potential of Exoskeleton in the Malaysian Construction Industry

Fong Jun Kai[1] **& Aryani Ahmad Latiffi**[1*]

[1]Department of Construction Management, Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia (UTHM), 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA

*Corresponding Author

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Abstract: The construction industry is a physically demanding and labor-intensive industry that requires a lot of manual handling of materials and awkward working postures. The great majority of tasks in construction projects, such as lifting or moving materials, plastering, paving and surfacing, scaffolding, and more, involve a lot of labours. Exoskeleton is a technology that has the potential to decrease the risk of injury of workers in the construction industry. This technology is being implemented widely in developed countries and has the potential to be implemented in developing countries such as Malaysia. Therefore, the objectives of this research are to identify the current level of understanding of the technology, the challenges that exoskeleton will encounter in the Malaysian construction industry and the ways to promote exoskeleton in the industry. This research was carried out through a questionnaire survey. A total of 90 respondents participated in the survey and gave their responses to the questionnaire form. The findings from the survey revealed the future potential of the exoskeleton in the Malaysian construction industry. The level of understanding of exoskeleton in the Malaysian construction industry was at a high level. The main challenge that the exoskeleton will encounter is cost. The cost of this technology involved in acquiring maintaining and updating technology fees. Hence, the respondents agree that the government plays a great role in promoting the use of the exoskeleton in the construction industry. In conclusion, exoskeleton has the potential to contribute to lessening the number of injuries of workers in the construction industry.

Keywords: Construction industry, Exoskeleton, Malaysia, Potential

Corresponding author: aryani@uthm.edu.my

1. Introduction

The construction industry in Malaysia has made a substantial contribution to building the infrastructure needed for social development and directly promoting economic growth (Tajuddin *et al*., 2015). According to statistics on injury and fatality rates, work-related mortality, workers' compensation, and injury rates, the construction business has been named one of the most dangerous industries in many regions of the world (Chong *et al*., 2014). The great majority of tasks in construction projects, such as lifting or moving materials, plastering, paving and surfacing, scaffolding, and more, involve a lot of labours. Performing these physical tasks puts workers at a high risk of injury due to constant wear and tear (Zhu *et al*., 2021). One of the acceptance technologies that could improve the risk (injury) is using the Exoskeleton. This section discusses the research background, problem statement, research questions, research objectives, research scope and significance of research.

Exoskeleton is the technology that potential to decrease the risk of injury of workers in the construction industry. The exoskeleton is a wearable machine with motorized joints that help to reduce strain and injury by providing lift support, weight distribution, posture correction, and other functions. Wearable technology is taking on a different meaning in the world of construction. Exoskeleton technology comes in a variety of shapes and sizes, some of which are powered by batteries and others by mechanical components that store energy (Butler, 2016). The exoskeleton technology is an electromechanic system that can give humans extra strength to resist figures or to take more weight, run faster, or jump higher. This technology is developed to help workers ease fatigue and help prevent injury (Li *et al*., 2014).

Exoskeleton can be divided into two (2) categories which are active, and passive based on the criterion of whether the system has a portable power supply or not (Li *et al*., 2014). The passive exoskeleton is a human interface that records motions of the right arm and upper shoulder to enable natural teleoperation of extremely sophisticated robotic systems. A passive system does not require an external power source and instead relies on materials, springs, or dampers that can store and release energy from human movements (Gull *et al*., 2020). Meanwhile, the active exoskeleton is a human interface for motion capturing and force interaction. The system is fixed at four points to the human body and can interact with the user at the upper shoulder, upper arm and forearm (Robotics Innovation Center, 2017). An active exoskeleton is made up of one or more actuators that actively boost the human body's power (Gul *et al*., 2020).

One of the industries with the highest risk of developing work-related musculoskeletal problems is the construction industry (Lop *et al*., 2017). Musculoskeletal problems and work-related injuries continue to be significant issues in the industry. Musculoskeletal diseases (MSDs) are conditions that affect the human body's muscles, tendons, nerves, and supporting structures. One of the main issues construction workers deal with is MSDs. The prevalence of MSDs in various body regions is noticeably higher in people who engage in physically demanding jobs (Deros, 2014). For construction workers, MSDs are a main cause of productivity loss at work, functional impairments and permanent disability (Boschman *et al*., 2012).

Lifting items repeatedly is a necessary part of manual material handling, which involves moving freight from distribution centres to trucks, trucks to pallets, and pallets to shelves. Lifting, pushing, tugging, holding, and carrying objects are among the motions that workers perform during the procedure (Chang *et al*., 2020). Construction workers are more susceptible to MSDs, one of the most prevalent occupational health issues. Additionally, MSDs pose a significant health risk to both the general public and construction employees. Muscles, tendons, ligaments, joints, nerves, and blood vessels can all be injured by MSDs (Lop *et al*., 2017).

Figure 1 shows that the industries with higher-than-average rates of musculoskeletal disorders, averaged 2018/19-2020/21. According to the Labour Force Survey (LFS), the entire number of cases of work-related musculoskeletal disarranges in 2020/21 was 470,000, a predominance rate of 1,420 per 100,000 specialists. These comprised of 212,000 cases where the upper appendages or neck was influenced, 182,000 where the back was influenced and 76,000 where the lower appendages were influenced. According to the most recent estimates from the LFS, the prevalence of work-related musculoskeletal diseases (WMSDs) was 1,130 cases per 100,000 employees on average from 2018/19 to 2020/21 across all industries. Construction had much higher rates than the norm for all industries (1,830 cases per 100,000 workers), as did Human health and social work (1,500 cases per 100,000 workers).

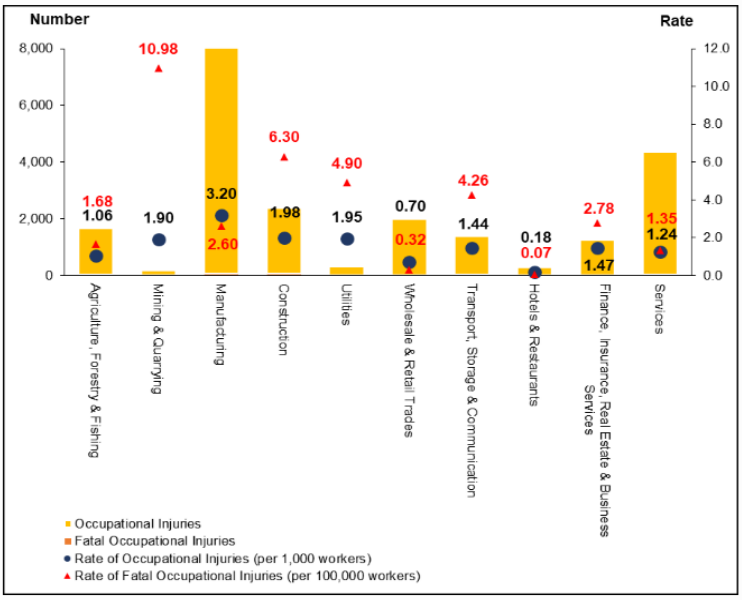

Figure 1: Industries with higher-than-average rates of musculoskeletal disorders, averaged 2018/19-2020/21. Retrieved from Work- related musculoskeletal disorders statistics in Great Britain 2021

There is no doubt that the construction industry is one of the leading causes of occupational injuries of WMSDs (Golabchi *et al*., 2015). The construction industry nowadays has centered more on moving forward productivity over guaranteeing safety and health issues of the construction labours such as conducting an ergonomic investigation or using advanced technology such as the exoskeleton to assist construction workers during work and decrease the health issues like WMSDs in the industry. Therefore, the objectives of this research are (i) to identify the current level of understanding of the technology of exoskeleton in the Malaysian construction industry, (ii) to identify the challenges that exoskeleton will encounter in the Malaysian construction industry, and (iii) to identify the strategies to promote the exoskeleton in the Malaysian construction industry.

This research is focused on the Klang area of Selangor while the respondents involved with this research were project managers, safety officers and project engineers of grade G7 contractor registered with the Construction Industry Development Board (CIDB) Malaysia in 2020. G7 contractor is classified as the highest grade in CIDB registration and tends to receive mega projects. Apart from that, these respondents have been chosen because of their power to make decisions in the process of completing a construction project.

This research can be a reference for students, researchers and academicians to explore and provide a better understanding of the exoskeleton in the industry. This research is also important to the construction players because it helps the players to get knowledge of exoskeleton in the construction industry. This research is meaningful to promote the exoskeleton technology to the Malaysian construction industry.

2. Literature Review

This section discusses on definition, purposes, benefits and challenges of implementing the exoskeleton in the industry. The discussion was made based on referring to the article journals, books, online resources and other documents that are related for academic purposes.

2.1 Exoskeleton

Exoskeleton has been around for a long time, and the military was one of the first to adopt them in the United States of America (USA). Exoskeleton has been developed, studied, and identified for nearly three decades by the USA Army Research Laboratory and its predecessors (Crowell *et al*., 2019).

The exoskeleton is a wearable device made up of links and joints that closely match the human body's structure (Gupta *et al*., 2020). Exoskeleton can be classified according to their sources of support and power. The human body, the exoskeleton framework, or external support like as a concrete floor can all be used as exoskeleton sources of support. The human body, exoskeleton framework, and motors can all be used as power sources for exoskeletons (Fox *et al*., 2019). Exoskeleton is a wearable that works with users, not robots that automate tasks rather than workers. Exoskeleton is mechanical devices worn by workers that enhance human performance. It can help construction workers reduce the high impact of their work and increase their productivity by allowing them to lift heavy objects, reduce fatigue, facilitate the use of tools in awkward positions and more (Seyrfar *et al*., 2022). Electric motors, pneumatic muscles, or hydraulic power can all be used to provide this external energy (Koening, 2020).

2.2 Purposes of Exoskeleton

Exoskeleton is a phrase frequently used to refer to a variety of applications with varying goals and there are different purposes of exoskeleton can be carried out.

2.2.1 Rehabilitation purpose

Exoskeletons are utilized to restore function in rehabilitation medicine. These gadgets, for example, allow people with spinal cord injuries or multiple sclerosis to walk with assistance. These devices can also be used as therapy equipment to help a person's muscles or nervous system recover from a handicap or as assistive devices to help restore function to an arm or leg. Industrial exoskeletons should be contrasted with these types of rehabilitation devices. The purpose of an industrial exoskeleton is to improve, amplify, or strengthen the performance of a worker's already-existing body parts, especially their lower back and upper extremities (Howard *et al*., 2020).

2.2.2 Enhance physical performance

Robotic exoskeletons are wearable electromechanical devices that have been created as orthotic devices for gait rehabilitation or locomotion support, as well as augmentative devices to improve the wearer's physical performance. These enable users with appropriate physical abilities to stand, walk, climb stairs and perform activities of daily living (Miller *et al*., 2016). Exoskeletons are wearable devices placed on the user's body to augment, enhance or restore human performance. Materials range from metal and carbon to fibre, soft and elastic parts. Factory workers using the exoskeleton experienced less back and shoulder pain, and they were able to do more physical activity after getting off work.

2.2.3 Reduces stress

The exoskeleton reduces stress on the body by transferring the weight of the user's arms from the shoulders, neck and upper body to the core of the body. When the user's arm is raised, the mechanical support system is activated and transfers the weight through a network of cables, pulleys and springs as the arm is lowered (Robotic Industries Association (RIA), 2019).

2.3 Potential and Benefits of Exoskeletons

With the use of an exoskeleton, which can support or assist body postures or motions during tasks, workers were expected to be able to do jobs more effortlessly and successfully (Kim *et al*., 2019). Exoskeletons clearly have the potential to help manipulate heavy loads in the nonmilitary context, where they could assist factory, construction, and other manual workers (Bogue, 2015). The following are more on the potential and benefits of exoskeletons:

2.3.1 Avoid injuries

A wearable low-back support or stooping-assist exoskeleton can also help to alleviate mechanical loading on the lumber spine, particularly compression force. They can help to reduce the uncomfortable trunk posture that occurs when stooping and bending, as well as nerve irritation and spinal muscle stress, while executing construction tasks. Exoskeletons can help workers avoid injuries and promote a healthy work environment. A comfortable wearable knee exoskeleton can allow construction workers to squat repeatedly or for long periods of time by lowering quadricep muscle knee forces. This can considerably lessen the amount of work needed from the knee muscles to execute a job, lowering the strain on the knee joint and minimising muscle fatigue (Zhu *et al*., 2021). This is critical since construction workers' repeated and physically demanding activities can result in severe strain, injuries, and lasting disability.

2.3.2 Ageing problem

Exoskeletons can also assist in addressing the issues brought on by an ageing construction workforce by enabling older people to continue working and performing physically demanding activities (Delgado *et al*., 2019). Hopes for the benefits of industrial exoskeletons have been surpassed by the growth of the commercial sector. Artificial exoskeletons are expected to increase productivity through the decrease of physical weariness, time-to-completion metrics, brisk product inflow rates, and improved first-time quality checks, however, similar predictions could be overstated (Panetta, 2017).

2.3.3 Reduce risk with WMSDs

The promise that industrial exoskeletons could potentially reduce risk factors associated with WMSDs, reduce medical costs for WMSDs, and reduce lost workdays is the expectation that has gotten the most attention from an occupational health and safety standpoint (Lu *et al*.,2018).

2.4 Challenges of Using Exoskeletons in the Construction Industry

In the traditional construction industry, there are still consist many challenges in using the exoskeleton technology. Although the technology can be a great solution for the traditional construction industry there are still numerous issues that need to be resolved.

2.4.1 Cost of the product

The cost of a product is a more complex issue that is influenced by government policy and the insurance industry. There is a consensual belief among the main players in the rehabilitation Eco-system that the price of robotics is unrealistically high to be adapted widely (Soltani-Zarrin *et al*., 2017). Robotic exoskeletons have a high initial purchase price, yearly maintenance costs, and user-specific training expenditures. While many modern technologies can be inefficient in terms of cost, others have been shown to be either cost-neutral or cost-saving.

2.4.2 Lack of training hinders.

Lack of training hinders using exoskeleton beneficially is one of the challenges (Bances *et al*., 2022). It investigated whether special skills are necessary to use exoskeletons beneficially and, if so, what the adequate training strategies are (Wortmeier *et al*., 2021). Notwithstanding the far-reaching influence on daily work processes, exoskeletons are not used as technologies that require special skills and training. A brief presentation by a sales representative into the technical essentials is frequently considered to be adequate for further use. However, it turns out that abilities are required and must be provided, as the taking-after case appears. Workers employed exoskeletons for connecting and glueing timber bars during exoskeleton demonstrations in timber building enterprises. They might not have moved as consistently, felt unstable while interacting with the exoskeleton, and lacked the skills necessary to function in today's workplace. A belt that across their upper backs chafed them too much. One employee did so by putting the belt around their neck. At this point, the sales representative mediated and clarified that typically ergonomically perilous. Exoskeleton ergonomics and the reflection of one's claim development designs with exoskeletons knowledge proved to be incredibly important for achieving the desired health impacts.

2.4.3 General discomfort

Besides that, other challenges to acceptance include general discomfort, for example, a chest pad of a back assist exoskeleton making inconvenient contact with the thoracic region. According to Hensel & Keil (2019), heat discomfort has been described, and it can be exacerbated in hotter climates during the summer. Exoskeleton adoption can be aided by a detailed model of factors that support positive acceptance of exoskeletons. To summarise, methods to assess an exoskeleton's readiness for use in specific work environments are required.

2.4.4 Imperfect development

According to Howard *et al*., (2020), since the current development of artificial exoskeletons focuses on specialised details without considering organisational factors or product conditions unconnected to muscular loads, the current commercially available artificial exoskeletons are not at an advanced enough position of readiness for the utmost workplaces. For example, enterprises may arise about the operation of exoskeletons in surgical operating apartments by medical labour force. In the operating room, labour force is not allowed to wear anything below the elbow joint (Dahmen *et al*.,2018). Exoskeleton design for operating room workers may be difficult given this organisational task need. When a new technology, particularly a wearable technology is introduced, the level of trust between employees and employers serves as a crucial safeguard against the abandonment of exoskeletons in the workplace. The use of any new technology requires that several conditions be satisfied including beliefs about performance expectations.

2.5 Work-Related to Musculoskeletal Disorders (WMSDs)

According to Lop *et al*., (2017), construction workers are at a high risk of developing Work-Related Musculoskeletal Disorder (WMSDs) that are associated with exposure factors in this work environment. Despite the high prevalence of ergonomics risk factors in construction work, research has been limited in this industry. The cost of WSMDs is considerable since they are connected with direct worker compensation (Ekpenyong *et al*., 2014). According to Rwamamara (2005), the direct costs of musculoskeletal disease reimbursement far outweigh the indirect costs associated with productivity and quality disruption, worker replacement costs, training and absenteeism costs. Therefore, focusing on health and safety issues at the design stage can have a significant impact on reducing the risk of injury and the costs associated with health and safety-related project delays.

WMSDs incorporate numerous side effects but allude to a single fundamental family of clutter influencing the tissue of the musculoskeletal framework, counting ligament, muscles, tendons, bones, nerves, and vascular structures and are ordinarily restricted to upper limit and lower back. This clutter is presently being recognised as a driving cause of critical human enduring, misfortune of efficiency and financial misfortune to society. In today's cutting edge mechanical world, numerous occupations, such as gathering and destroying action in development businesses, may result in musculoskeletal clutters of the upper limits. These jobs include exerting long-lasting, boring stresses on the body's neck and bear region.

However, WMSDs can also be an acute trauma, such as a broken bone, that occurs during an accident. Symptoms can range from discomfort and pain to reduced and ineffective physical function. WMSDs cause injury and distress to workers, as well as financial loss due to disability, treatment costs, and lost income. They also have a huge negative impact on society as a whole. At the workplace level, this disruption can lead to costs as human capacity declines and production is disrupted. In addition to compensation paid through social insurance, social costs increase due to the need for treatment and rehabilitation. WMSD is not exclusive to any one sort of job activity and has an impact on a variety of construction vocations. Different construction industries face different physical workloads involving different parts of the body, and the incidence of WMSDs is much higher than in most other occupations (Holmström *et al*., 1995 and Schneider *et al*., 2001).

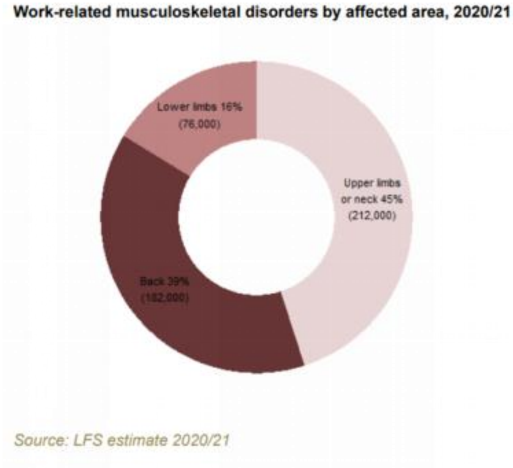

Figure 2: WMSDs by affected area, 2020/21 Retrieved from Work- related musculoskeletal disorders statistics in Great Britain 2021

2.6 The Musculoskeletal Disorders (MSDs)

The predominance of musculoskeletal disorders (MSDs) is expanding, as nearly development mechanical occupations include broad upper and lower back harm and all work wounds emerged from monotonous development or overexertion. The fundamental component for muscle activity is the musculoskeletal framework. Muscles, bones, and connective tissue make up this structure. Musculoskeletal injuries may have long-term affect on specialists and efficiency. Musculoskeletal injuries include torment within the hands, arms, shoulders, neck, back legs or feet whereas Musculoskeletal Disorders include muscles, bones, ligaments, nerves or other delicate tissues (Sentos,*et al*., 2014). MSDs are the leading cause of disability in people who have back pain or a disc disorder (McClymont *et al*., 2015). According to Lopet *et al*., (2017), those construction labourers who went to a healing center crisis room with intense musculoskeletal damage created inveterate indications.

Compared with male office workers and foremen in the construction industry, MSD symptoms were significantly higher in nine body regions across all construction industries, groups considered to have lower on-the-job exposures (Samuelsson & Andersson, 2002). MSD symptoms can affect all five body areas of the waist, knees, shoulders, wrists (hands), and neck in construction workers, and industries with the highest risk of each area.

2.7 Promote tools

2.7.1 Social Media

Social media promotion connects with the organisation's target audience, develops brand recognition, boosts online traffic, and boosts sales through websites like Facebook, Twitter, Instagram, LinkedIn, YouTube, and Pinterest. Running social media ads, creating content, communicating with consumers, and assessing the efficacy of the organisation's marketing strategies are all part of social media marketing (Samantha, 2021).

2.7.2 Role of Government

In accordance with economic statistics and the endogenous economic growth theory (Li et. al., 2019), analyse the mechanism of horizontal spillage and vertical spillage in the CRE that are experiencing the effect of science and technology project funding sponsored by the government.

3. Research Methodology

The section explains the research approach and method used to gain data for achieving the research objectives. This section describes the research design, data collection and data analysis.

3.1 Research Design

Research design is a framework for planning and carrying out a specific study. The design of the research is an essential component since it takes into account all four major factors: the strategy, the conceptual framework, choosing who and what to examine, and the methods and instruments to be utilised for data collection and analysis (Punch, 2013).

The quantitative approach was selected to gain data needed for this research. Leedy and Ormrod (2010) stated that quantitative researchers are looking for generalisable explanations and predictions that can be applied to other people and places. According to Creswell (2014), quantitative research identifies a research problem based on field trends or the need to explain why something happens. Quantitative research is defined as the systematic empirical investigation of observable phenomena using statistical, mathematical, or computational techniques, as stated above. Quantitative researchers aim to create a general understanding of behaviour and other phenomena across different settings and populations. Quantitative research is often fast, focused, scientific and relatable. In this research, researchers used a survey method to collect the data needed.

3.2 Data Collection

Data collection is divided into two parts which are primary data and secondary data. Both data are needed to make the research topic clearer and more understandable. The data gathering methods used in this study were critical in obtaining reliable data and information. Strong evidence and reasonableness are used to provide accurate facts and information.

a) Primary Data

Primary data is information gathered for the first time, usually through personal experiences or proof. It is also known as unprocessed data or firsthand information (Rabianski, 2003). For this research. A set of questionnaire form was designed to gain the primary data. The questionnaire made using the platform Google Form was distributed to the G7 contractor in the Klang area of Selangor. The questionnaire was distributed to the construction players in the stated area who can make the decision during the construction process.

b) Secondary Data

Information that has already been collected and recorded by other researchers for purposes other than the current study problem is referred to as secondary data. Secondary data are those that were gathered for a different reason and at a different time in the past by a person unrelated to the research endeavour. It can be found in the form of data compiled from a range of sources, including official documents, enumerations, internal records kept by organisations, books, journal articles, websites, and reports, among others. It also includes data that the researcher had earlier obtained (Kalu *et al*., 2019). It is critical to demonstrate the accuracy of the main data used in this research.

3.3 Sampling Design

Sample can be defined as the targeted set of respondents selected in representing individuals from a population while sampling is the act of selecting samples using a specific process or technique (Bordens & Abbott, 2011, Moser & Kalton, 2017). Simply put, sampling is the collection of data in smaller quantities with the goal of representing the entire population.

3.3.1 Population and Sampling Frame

The population for this research was construction players while the sampling frame included G7 grade contractors that specifically focused on project manager, safety officer and project engineer in Klang, Selangor. These respondents have been chosen due to their decision-making power during the construction process.

3.3.2 Sample Size

A great sample fulfills all the efficiency, representativeness, reliability, and adaptability requirements (Kothari, 2004). According to the Construction Industry Development Board (CIDB) Malaysia (2020), there were a total of 275 G7 grade contractors in Klang, Selangor. Thus, according to the table derived by Ahmad, H., & Halim, H. (2017), a sample size of 162 respondents is needed to suit the research. Figure 3.1 shows the table for determining the sample size of a known population.

3.4 Pilot Test

A pilot test is essentially a practice distribution of a questionnaire before the actual data gathering. As a result, a pilot test was undertaken to reflect on and amend the questionnaire in order to improve its viability (Ruel *et al*., 2016). The pilot test was done by the researcher before starting the data collection phase and the proposed target sample size for the pilot test is 10% less than the actual goal sample size for appropriate results.

3.5 Data Analysis

Data gained by using the questionnaire form distributed to the respondents were analysed by using the Statistical Package for Social Sciences (SPSS) statistical tool Version 26. The data were summarised in table and graph during data analysis, and secondary data was used to supplement the primary data collected through survey distribution. The descriptive and inferential analyses were employed, and the data's reliability and validity were assessed.

TABLE 1
Table for Determining Sample Size from a Given Population

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Note.—*N* is population size.
S is sample size.

Figure 3: Table for determining sample size of a known population (Ahmad, H., & Halim, H. (2017))

4. Results and Discussion

This section presents the result and the discussion of the data and analysis of the research. This research aims to identify the current knowledge on the technology of exoskeleton in the Malaysian construction industry, the challenges that exoskeleton will encounter in the Malaysian construction industry and the strategies to promote the exoskeleton in the Malaysian construction industry.

4.1 Pilot Test Result

Table 1: Reliability statistic of overall pilot test

Cronbach's Alpha	N of Items
0.852	29

Table 1 shows the result of the reliability test for this research. There were 12 data collected in the pilot test of this research. For the overall variables' reliability statistic, the Cronbach's Alpha coefficients of overall variables are 0.852 which measured by 29 number of items. The Cronbach's Alpha is more than 0.7 which is 0.852, it means that this pilot test is reliable. Hence, it can be indicated that the items have appropriate instrument internal consistency.

4.2 Respondent's Background

This section presents about the 90 respondents' information that take part in answering the questionnaire. The purpose of this section is to ensure the questionnaire has been delivered to the related respondent. Table 2 below shows the respondents' information.

Table 2: Respondents' background

No	Description	Frequency	Percentage (%)
1	Occupation		
	Project Manager	36	40
	Safety Officer	27	30
	Project Engineer	27	30
2	Working experience in the Malaysian construction industry		
	1-5 years	31	34.4
	6-10 years	55	61.1
	11-15 years	4	4.4
	16 years and above	0	0.0
3	Highest Education Level		
	PhD	0	0.0
	Master's degree	3	3.3
	Bachelor's Degree	60	66.7
	Diploma	21	23.3
	STPM	4	4.4
	SPM	2	2.2

Based on the Table, 3 questions were asked of the respondents. The questions were on occupation, working experience in the Malaysian construction industry and highest education level. The result shows that the majority of the respondents work as project manager which is 36 respondents (40%), and comes with safety officer and project engineer which are same number of respondents which are 27 of them and 30 % of the total respondents. Furthermore, the majority of the respondents have 6-10 years of working experience in the Malaysian construction industry which is 55 of 90 respondents and 61.1 %. Besides, there are 31 respondents (34.4%) have 1-5 years of working experience in the Malaysian construction industry. Next, there is a minor of respondent with 11-15 years of working experience in the Malaysian construction industry which are recorded as 4 out of 90 respondents (4.4%) and there is no respondent with 16 years and above working experience in the industry. For the highest education level, there are 2 respondents with SPM, which is 2.2%. 4 respondents have qualification in STPM (4.4%) and the majority of respondents are qualified with the Bachelor's degree level which is 66.7% (60 respondents). The following is the Diploma education level which is 23.3% (21 respondents). There is only 3.3 % of respondents (3) have having Master's degree.

4.3 Current knowledge of the technology Exoskeleton in the Malaysian construction industry.

A summary of the first objective which is identifying the current knowledge of the technology exoskeleton in the Malaysian construction industry is discussed in this section. The index mean generated by SPSS was used to obtain the level of agreement of respondents towards the questions and it is summarised in Table 4 and Table 5. These questions are translated in the form of average mean and standard deviation to get the average range level which is low, medium and high. Table 3 is used as a reference for the degree of tendency of each question involved.

Table 3: Average measurement level (Nor Aziati *et al.*, 2016)

Average Range	Degree of central tendency
Low	1.00- 2.33
Medium	2.34- 3.66
High	3.67- 5.00

Table 4: Current knowledge of the technology exoskeleton in the Malaysian construction industry

No	What Exoskeleton is	Mean	Category	Ranking
1	Wearable electromechanical devices that developed as augmentative device to enhance the physical performance of the wearer.	4.19	High	1
2	Wearable devices that work in tandem with the user.	4.16	High	2
3	Used to support body weight, assist with lifting, help maintain loads or stabilize the user's body.	4.14	High	3
4	A form of wearable technology that are equipped with motorized joints	4.00	High	4
5	Can be classified as active and passive exoskeleton which active exoskeleton has a portable power supply, but passive exoskeleton has not.	3.86	High	5
6	Utilised to restore function in rehabilitation medicine.	3.79	Medium	6
7	Designed to augment the user's strength to enable the lifting of heavy objects from the early 1970s.	3.69	Medium	7

Based on Table 4, shows that the wearable electromechanical devices that developed as an augmentative device to enhance the physical performance of the wearer is ranked 1 with a mean of 4.19 which represent the central of tendency is high. The average level of understanding of the technology of exoskeleton in respondents is high and only showed that 2 out of 7 questions given to the respondent showed that respondents have a medium level of understanding from the average mean score.

Table 5: Benefits of exoskeleton technology for the construction industry

No	Benefits of Exoskeleton technology for the construction industry	Mean	Category	Ranking
1	Fewer chances of getting injured such as the cases of overexertion and fatigue lead to injuries in the workplace.	4.44	High	1
2	Reduce healthcare and disability costs such as decreasing the musculoskeletal disorders cases among construction workers.	4.31	High	2
3	Provide excellent support to the workers' posture and reduce strain on the muscles.	4.31	High	2
4	Reduce the lost workdays by reducing the risk of the worker being injured while working.	4.30	High	4
5	Increase productivity due to the reduced strain, construction exoskeleton users experience less weariness and can finish more work than their bodies can normally handle.	4.29	High	5

6	Contractors who are generally restricted by their age or physical limitation can participate in more difficult operations with the technology exoskeleton.	4.26	High	6
7	Increase efficiency because it can make large objects easier to move and decrease the impact of holding heavy machines for extended periods of time.	4.23	High	7
8	Decrease worker injuries on site by decreasing the pressure that repeated labor and protracted jobs place on joints and muscles.	4.22	High	8

Table 4.5 above shows the benefits of the exoskeleton technology for the construction industry. The central tendency shows that all of the questions in this section are at a high level. The respondents identified the fewer chances of getting injured such as the cases of overexertion and fatigue leading to injuries in the workplace as the rank 1 benefit among the options with a mean score of 4.44. The respondents show a high level of agreement on the benefit of technology exoskeleton will benefit fewer chance of getting injured such as the cases of overexertion and fatigue lead to the injuries in the workplace.

4.4 Challenges that exoskeleton will encounter in the Malaysian construction industry

The results of the challenges that exoskeleton will encounter in the Malaysian construction industry are shown in Table 6.

Table 6: Challenges that exoskeleton will encounter in the Malaysian construction industry

Challenges that exoskeleton will encounter in the Malaysian construction industry	Mean	Category
It is a costly technology that involves acquiring, maintaining and updating technology fees.	4.31	High
It might limit the users' movement since some models of exoskeletons are bulky or clumsy.	4.27	High
Lack of materials that are suitable weight to be used in exoskeletons.	4.27	High
The current development of artificial exoskeleton focuses on specialised detail without considering organizational factors or product conditions unconnected to muscular loads.	4.40	High
Power supply of the exoskeleton limits the mobility of users.	4.23	High
The time and training expenses required to produce qualified people with the required knowledge can be demanding.	4.21	High
Lack of trainer in transferring the robotic knowledge to the operator of the exoskeleton.	4.09	High
Lack of the robotic knowledge from the worker to operate the exoskeletons.	4.10	High

According to the Table, the challenges of all of the central of the tendency are high. The challenge that hit the highest mean score of 4.40 is the current development of artificial exoskeleton focuses on specialized detail without considering organisational factors or product conditions unconnected to muscular loads. The most agreement on the challenges that will encounter is the current development of artificial exoskeleton focuses on specialised detail without considering organisational factors or product conditions unconnected to muscular loads.

4.5 Strategies to promote the exoskeleton in the Malaysian construction industry

The result of the strategies is shown in Table 7.

Table 7: Strategies to promote the exoskeleton in the Malaysian construction industry

No	Strategies to promote the exoskeleton in the Malaysian construction industry.	Mean	Category	Ranking
1	Government can increase the rate of return for the technology exoskeleton and encourage its development. For example, direct government funding of Research and Development (R&D), and tax incentives for R&D.	4.44	High	1
2	Cooperate with the foreign company that already using the exoskeleton technology to understand the benefits and the disadvantages.	4.42	High	2
3	Holding a workshop where can help employers understand the advantages that exoskeletons will bring with them.	4.39	High	3
4	Use social media as a promotional strategy, for example, online websites, Instagram, Facebook and YouTube.	4.36	High	4
5	Provide training and learning opportunities to the employee. For example, employees should be trained on the best practices for the technology and basic functionality.	4.34	High	5
6	Reduce the materials fee by giving the allowance to the R&D department.	4.32	High	6

Table 4.7 shows the strategies to promote the exoskeleton in the Malaysian construction industry. The first rank (Rank 1) of strategies is the government can increase the rate of return for the technology exoskeleton and encourage its development. For example, direct government funding of Research and Development (R&D) and tax incentives for R&D with the mean score of 4.44. Government can increase the rate of return for the technology exoskeleton and encourage its development is the most agreement among the 90 respondents.

4.6 Discussion

The researchers could assert that every research objective listed in literature review, including the level of understanding, challenge will be encounter and strategies to promote the exoskeleton in Malaysian construction industry, was appropriate based on the data collection and analysis process. Each respondent provided opinion entries to support the previous researcher's assertion. The relationship between the literature review and the respondent data was identified by the researcher.

The first objective was achieved because the result from the data collected are agree by the respondent that the exoskeleton is "Wearable electromechanical devices that developed as augmentative device to enhance the physical performance of the wearer." and this can be agree by the statement that exoskeletons are electromechanical devices that a human operator wears and are intended to improve the wearer's physical performance (Hill, *et al*., 2017). Since, ten years ago, advancements in robotics and mechatronics technology have led to a substantial growth in exoskeleton technology (Hill, *et al*., 2017).

Next, the second objective was stated as achieved because the result from the data collected are all in the high agreement from the question and the cost for this technology has become the highest agreement among the respondent and it was agreed by the statement from construction tips (2020), even the most basic variants of the exoskeleton are expensive, costing thousands of dollars. If several people used the exoskeleton to do a task, it would be more cost-effective for the organisation. Exoskeleton usage schedules may be managed by users using asset management software.

Lastly, the strategy that the most agreed by the respondents to promote this technology is government play an important character because government can increase the rate of return for the technology exoskeleton and encourage its development. For example, direct government funding of Research and Development (R&D), tax incentives for R&D. In order to advance technology and/or provide an atmosphere that encourages increasing private sector investment and the creation of initiatives that serve the public interest, the government sponsors several communication programmes.

5. Conclusion

The outcome of this research can provide a useful information and advantages for the related parties, especially for Malaysian construction industry. There are more benefits will bring up with the development of the technology of exoskeleton in the future and all related parties are encouraged to explore this technology to improve the Malaysian construction industry.

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