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A Preliminary Study in Rationalizing the Need for the Goldilocks Principle in Manufacturing SMEs

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Abstract. The Goldilocks principle has been widely used in the medical science and psychology fields. However, there appear to be many areas where this principle can be explored in social science research. The main objective of this study is to rationalize the need for the Goldilocks principle by observing the effect of fatigue and stress on human error in manufacturing SMEs. A total of 190 questionnaires were collected and analyzed in SmartPLS version 3. It was found that the alternative hypotheses were supported with p-values below 0.05. The authors suggested that manufacturing companies should set a work record of the task completion time and consider the average time as grace duration in performing the task. An organization is advised to refrain from giving extra time or too little time in completing a task. The timeframe should be based on the task complexity or task familiarity of the overall organization. This study benefits the manufacturing companies as it can serve as a guideline on HR policies and working hours.

Keywords: goldilocks principle, human error, manufacturing SMEs, workplace accidents and injuries.

1. Introduction

Studies on the Goldilocks principle are widely used in medical science, psychology, and engineering research (Nicklaus 2021; Hennige 2021; Bakhoum et al., 2021). The principle was inspired by the story of “Goldilocks and the Three Bears” where the emphasis was placed on a little girl named Goldilocks who would only eat the bowl of porridge that was ‘just nice’ in regard to temperature, rather than the other bowls of porridge which were ‘too hot’ and ‘too cold’. The Too-Much-of-a-Good-Thing Effect (TMGT) may occur when ordinarily beneficial antecedents or the predictor variables reach optimal points after which their relations with desired outcomes/criterion variables cease to be linear and positive (Balas-Timar et al., 2015). Nevertheless, in the concept of economics, the ‘diminishing marginal of utility’ explained that the more of something you have, the less of it you want. This optimization theory explained that setting up a limit for every task is relatively important. The extremist or overly done will cause consequences in performance. On the other hand, ‘too little’ effort will also cause delay of production and performance. In the workplace, both overworked and underworked conditions are equally dangerous as they may cause a drop in productivity or in a worst-case scenario, workplace accidents, and injuries. Many workers in Malaysia reported stress and anxiety in the year 2020, a year which was considered one of the most stressful years in the history of the global workforce (Teoh 2021).

In the workplace, especially in the assembly line of manufacturing small- and medium-sized enterprises (SMEs), there are many who perform highly repetition and/or monotonous jobs at a given time. Escorpizo and Moore did an experiment in 2015 on repetitive force with error count and concluded that there is a significant relationship between repetitive force and human error (Escorpizo et al., 2007). On the other hand, a monotonous job will cause fatigue and boredom. Thus, it can be summarized that jobs with low and high repetition can influence human error in the workplace.

The Goldilocks principle can be applied in manufacturing assembly. A worker should not be given too much work or too little work; it must be just right (Goldenhar et al., 2003). Many workplace accidents and injuries occur due to the high stress of employees in the manufacturing plants (Yeow et al., 2014). Many physchologists and sociologists around the world agreed that ‘stress’ has several different meaning for different types of people as well as different condition (Fink 2009). There were three-components in the definition of stress which includes, the increase or arousal of behavioural (motor) activity, the escalation of neurochemical level, and/or the lack of control over an aversive experience will cause stress to an individual (Fink 2009). In the manufacturing industry, the common behavioral activities such as high mental workload and high repetitive jobs are the main source of stress. In 1932, Bartlett did a ‘War of the Ghost’ experiment on human error and found that longer-term memory or heavy mental stress resulted in increased human error (Carbon et al., 2012; Reason

2000). No doubt, working in a manufacturing plant requires memorising steps and actions, and potentially very long working hours. The 'just right' or 'cut-off range' for work is unknown although the standard regulation includes 8 working hours per day. Any work performed beyond 8 hours per day or 48 hours per week would be considered overtime. To earn extra income, workers often consider working overtime, but this significantly increases the exhaustion and leads to more human error in the workplace (Goldenhar et al., 2003). Therefore, the objective of this study is to rationalize the need for the Goldilocks principle by observing the effect of fatigue and stress on human error in manufacturing SMEs, and suggest ways in preventing the over-do-it or under-do-it culture in manufacturing SMEs.

2. Literature Review

2.1. Human error affecting workplace accidents and injuries in the manufacturing SMEs

Human error is a major contributor of workplace accidents and injuries, accounting for over 90% of total workplace accidents. Research shows that two out of three workplace accidents are mainly caused by human error (Williamson et al., 1997). There are more than 3000 workplace accidents and injuries occurring in Malaysia almost every year and most of the accidents involve victims in manufacturing industries (Yeow et al., 2020). Besides that, human error is also considered "a generic term to encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency" (reason et al., 1990). Therefore, in short, human error can be considered as any mental or physical activity that fails to perform appropriately, leading to an undesirable outcome.

In 2019, the reported workplace accidents and injuries for manufacturing were above 4900 cases (Yeow wt al., 2020). According to the Department of Occupational Safety and Health (DOSH), the incident rate of workplace accidents and injuries was 3.38, with a fatality rate of 4.62 per 1000 workers in 2013, whereas in the year 2014, the incident rate was 3.1 and the fatality rate was 4.21 per 1000 workers. To date, the statistic is still between 2 to 6 deaths per 1000 workers in Malaysia. Although there is a slight decrease in the rate, the risk is still very high. Undoubtedly, workplace accidents, and injuries are one of the major concerns for both employers and employees.

The preceding literature sets a precedence that workplace accidents bring several negative impacts to the manufacturers. According to researchers Zakaria et al., (2012), several precautionary steps must be implemented to prevent workplace accidents and injuries. Such measures require research from diverse areas in investigating the causes of workplace hazards. In addition, studies also seem to point out that human error is possibly a main contributor to workplace accidents and injuries.

2.2. The generic error modeling system (GEMS)

The Generic Error Modelling System (GEMS) is an extension model of Skill-Rule-Knowledge (SRK) framework by Rasmussen in 1979 and mentioned by Reason 1990 (Reason 1990). This model described how error occurs at skill-, rule-, and knowledge-based levels in a task (Refer to Figure 1). In the skill-based level, errors happen due to paying too low attention on specific task or even over-attention to a certain performance. The error of skill based usually caused by the homogeneous workload or similar job scope of a worker. Based on this model, when a problem occurs in the initial stage, the solution is at a rule-based level. This means that there is a need to audit the 'rules' or regulations of the workplace as there might be a problem with the 'rules' in the organisation. Therefore, implementation or rules enforcement is important in the workplace. On the other hand, if the solution is not related to rules-based levels, it will move down to another level of error known as the knowledge-based level such as failure of implication of the system (Yeow et al., 2020). In this level, it shows that the workers required training or given proper orientation regarding the system or production lines. In most cases, there is a need to educate new employees and supply them with enough time to cope with the new working environment before allowing them to engage heavier or more complex tasks. For skill-based error, the cause of the error is a lack of highly practiced jobs or movement of physical actions, and little to no alertness in the monitoring of job performance.

Based on Rasmussen's SRK framework and Reason's GEMS framework, it can be summarized that skill-based errors are more prone in occurring especially in the manufacturing industry. In the manufacturing operation plants, the involvement of hands-on repetition job is very common. Based on Leiden and Wood's (2001) study, errors such as attention slips, memory lapses, and perceptual errors contributed 14.28%, 11.18%, and 57.13% respectively based on the 'Percentage of Mishaps by Error Type'.

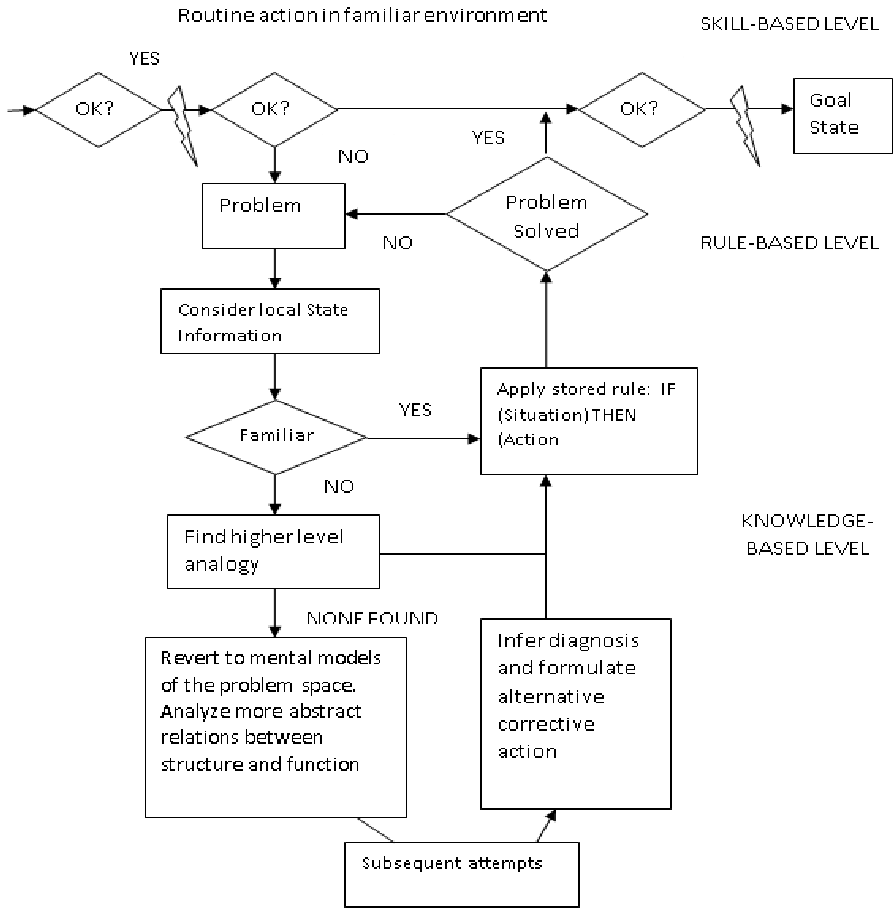

Fig. 1: Generic error modelling system (GEMS Framework).

Source: Adapted from Reason (1990)

2.3. Fatigue and high mental workload-stress

As defined earlier, high mental workload is the common stress among manufacturing workers. Stress inarguably impacts people's concentration, leading to unclear thoughts, poor decision-making, as well as memory loss (Setterlind et al., 1995). Psychology researchers have been trying to identify the extended mental workload limit of a worker in performing a task as well as the ability to cope with the task (Rubio et al., 2004). In summary, mental workload or stress level can be subjectively perceived by each individual who may be still willing to keep well-paying jobs while realising that high mental workload could be a risk factor of accidents (Paxion et al., 2013). Human error can occurred intentionally or unintentially when the mental workload is relatively high (Paxion et al., 2013). This is due the stress from eustress to distress. The distresses are somehow more dangerous as it may cause loss of focus and attention resulting anxiety. This notion explains that mental workload is significantly related to human error. Moreover, lean production or zero-defect production needs a high level of cognitive demand, and the relationship between the human error and cognitive demand in some studies is significant (Berggren 1993). Therefore, the first hypothesis is proposed as:

H1: There is a significant relationship between high mental stress and human error in manufacturing SMEs

On the other hand, fatigue in workplace is also very common. Fatigue will significantly cause an error in production (Reason 2017). Normally, fatigues causes a worker to feel sleepy, feel tired, become bored, lack concentration, and experience blurry vision. All these symptoms will cause more errors or mistakes in the work and in worst scenario; it may cause injuries and accidents due to ‘unaware’ or ‘negligence’. Therefore, monitoring a worker’s fatigue level is, without a doubt, very important. Based on a previous study, work related to psychomotor performance includes the highest level of fatigue, especially in production plants (Charlton et al., 2001). Workers in manufacturing SMEs normally perform many high-level psychomotor job tasks. Therefore, a study related to fatigue and human error is important as workers need to learn how to cope with fatigue to prevent human error (Thoft-Christensen et al., 1996). Workers who are able to cope with fatigue often perform fewer errors compared to others who are less durable to fatigue (Saurin et al., 2004).

In the SMEs manufacturing industries, fatigue be consider as a range of distress and significantly causing drowsiness or low concentration whereas for high mental workload usually occurred when workers in the assembly lines were given multiple tasks to complete on time. Incompetent workers in SMEs will feel uneasy. Mental workload is the portion of work stress required to meet the cognitive task demand. Fatigue or boredom in the workplace can lead to a large number of defects in production, which in turn leads to elevated stress levels, and possibly, a high production error in the manufacturing industry (Yeow et al., 2014). Hence, fatigue and stress are unavoidable when a person is performing similar tasks for a long period of time. There are studies mentioned that fatigue and stress can be controlled if a worker is given sufficient break times or proper work schedules. This is mainly because fatigue and stress are caused by long hours of work, lack of sleep, or the requirement to perform a task that may reduce one’s concentration, resulting in human error. On average, a human needs approximately 7 to 8 hours of sleep, and with less than 2 to 3 hours of sleep a day, one may experience memory loss, cognitive decline, and time-on-task decrement (Gravin 2011). These effects are harmful and may be the contributors to human error, and workplace accidents and injuries. Therefore, the second hypothesis can be proposed as:

H2: There is a significant relationship between fatigue and human error in manufacturing SMEs

3. Research Methodology

As for data collection, a sum of 400 questionnaires was sent via online emails to the registered companies under the Federation of Malaysian Manufacturers (FMM). The researchers received the FMM directory from one of the centres in Melaka. A probability sampling method was adopted in this study where the researchers clustered the respondents based on geographical location. Three main states (Selangor, Kuala Lumpur, and Johor) were selected, and a simple random method was adopted to select the 400 respondents. The respondents are the middle level managers either the HR department or the administration managers as they are the person that reasonable in filing a report of workplace accidents and injuries to the Department of Safety and Health (DOSH) or SOCSO. The process of data collection took approximately 6 months to obtain a minimum sample size.

Table 1: Result - measurement model.

Construct	Items	Loading	Cronbach's Alpha	rho_A	CR	AVE	F square	R square
Fatigue	FA1	0.8823	0.9225	0.939	0.951	0.867		
	FA2	0.8538					0.148	--
	FA3	0.8038						
Human Error	HE1	0.7848	0.7552	0.862	0.913	0.778		
	HE2	0.8106					--	0.3117
	HE3	0.8624						
Stress	SS1	0.9349	0.8040	0.810	0.884	0.717		
	SS2	0.9641					0.1012	--
	SS3	0.8923						

Table 2: Disciminant validity (heterotrait-monotrait ratio (HTMT).

	Fatigue	Human error	Stress at work	VIF
Fatigue				1.256
Human error	0.5880			
Stress at work	0.5810	0.5248		1.256

Table 3: Direct effect between independent variable and dependent variable.

	Human error
Fatigue	-0.3585
Human error	
Stress at work	0.2958

Table 4: Result - structural model.

Relationship	Std. Beta (β)	t-Value	P Values (<0.05)	Decision
H2: Fatigue -> Human error	-0.3600	3.5626	0.0004	Support hypothesis
H1: Stress -> Human error	0.2984	2.9070	0.0038	Support hypothesis

After several reminders were sent to respondents, the researchers obtained 190 questionnaires from the manufacturing SMEs. According to Hair et al. (2012), a sample should be at least a total of 10% of the overall population, and 400 respondents were selected out of 3500 registered manufacturing companies in FMM, producing a sample of at least 10% of the population. The collection rate was 47.5%, which is a response rate that is above 40%. Studies suggest that a response rate above 40% from online emails is considered adequate (Sheehan 2000).

Due to the small sample size of 190 respodents, this study used SmartPLS version 3. to analyse the data. Besides that, the research objective is to determine the effect of both fatigue and stress on human error in manufacturing SMEs by adopting the GEMS Models. Hence, SmartPLS version 3 is suitable for such an analysis (exploratory research for theory development) (Babib et al., 2015).

Add on, this research also used secondary data collection,. The researchers accessed data through journals, government statistics data from open websites, internet, also books related to research methodology.

4. Data Analysis

This study used SmartPLS version 3.0 to analyse the data (Shmuele 2019). Table 1 presents the results of the measurement model, and Table 2 shows the Discriminant Validity using the heterotrait-monotrait ratio of correlations (HTMT) of the study (Hair et al., 2018). To assess the partial least squares-structural equation modelling results (PLS-SEM), the author presented the measurement model in Table 1.

For a reflective measurement model, the indicator loading values should be equal to or greater than 0.7, and by referring to Table 1, all the item loadings ranged from 0.78 to 0.97. The evaluation of "internal consistency reliability is done using Jöreskog's (in the year 1971) composite reliability (CR)", in which the acceptance value of CR is above 0.8 (Hair et al., 2013). From Table 1, the CR values for all 3 variables are between 0.884 and 0.951. Subsequently, the "measurement model also includes the convergent validity" which is "the extent to which the construct converges to explain the variance of its items and the metric used is the average variance extracted (AVE)" (Hait et al., 2018). The acceptable AVE value is above 0.5. Thus, Table 1 shows that the AVE for all three variables is above 0.5 ranging from the values of 0.717 to 0.867. The F square value for Stress is 0.1012 whereas the effect size of Fatigue is 0.148, which is very close to 0.15. An F square value represents the effect size of the variables, and Cohen's d effect size values are normally classified as 0.02, 0.15, and 0.35, with each value representing small, medium, and large effects, respectively (Cohen 1988). From this study, fatigue has a medium effect size on human error whereas stress has a small effect size on human error in manufacturing SMEs. The threshold value of discriminant validity (HTMT value) is below 0.9, which reflects that discriminant validity has been established between these two reflective constructs.

Table 2 shows that the Variance Inflation Factor (VIF) is less than 3.3 which shows there are no problems with collinearity between the variables as the value is less than 5 (Henseler et al., 2015). The R square value of 0.3117 which helps to indicate the variance that there is 31.17% of human error explained by fatigue and stress. Table 4 shows that Hypothesis 1 and Hypothesis 2 are both supported. The relationship between Stress and Human Error is supported since the p-value is below 0.05 (β= 0.2984 and t-value= 2.907).The relationship between Fatigue and Human Error is also supported with a p-value of less than 0.05 (β= - 0.36, t-value= 3.5626). Interestingly, this finding shows that the workers have the perception that human error decreases as fatigue increases. However, this notion could be attributed to the induction of standard rest times in most Malaysian companies and the awareness of the Malaysian workers in utilizing these rest times whenever fatigue sets in. Such a self-regulating culture may have affected their perception of human error. Fatigue can be caused by long working times and by the execution of monotonous jobs. While workers who are not accustomed to taking rest breaks might make more errors attributed to a high level of fatigue, it is still possible for workers who perform a similar task for long hours to make less error if given enough time to rest. However, the "too slow and stagnant" emotional state of the worker may result in an effect known as the "zombie effect" where the workers become apathetic to work, and often spend many hours working with low motivation, little to no passion, and minimal connection to their work. Such a state is also very unhealthy for the workplace environment and workers' safety and health. Therefore, the researchers contend the importance of using the Goldilocks principle in the manufacturing industry to find a balance for workers such that they are not subjected to excessive stress or insufficient work-rest duration, which can lead to more human error.

5. Conclusion

In a nutshell, there is an urgent need of understanding the application of the Goldilocks principle in the manufacturing industry to reduce human error. This study found that excessive mental stress from work in manufacturing industries can significantly affect the performance of employees in regard to human error. While the causes of stress can include many factors, workplace stress in the manufacturing industry can be associated with heavy responsibility, excessive bureaucracy, coercive effects, or a culture of working overtime due to a shortage of workers. To reduce the level of stress, having an effective communication channel is important. The workers in the manufacturing industry should be well informed and very clear about their roles and responsibilities. Any newly assigned task should be informed, and the description should be highlighted to the employees. Moreover, if it is a new task, a longer grace period to complete the task is required. The grace period is highly dependent on the difficulty of the job. Mistakes or errors arise when there is time pressure, and causes stress at the same time. Therefore, there is a need to record the work task completion time for every organisational level, and apply the average time to be considered as the grace duration. The management should not emphasise on overly long work durations or even work durations that are too short when completing a task. The average time computed can be the threshold for all workers to follow. Such a guideline might help in reducing workplace stress and fatigue at manufacturing SMEs.

In Japan, companies with more than 50 workers are required to ask the employees to complete an annual stress check questionnaire designed to ascertain their mental health. This practice is endorsed by the Safety and Health Law in Japan. The manufacturing SMEs in Malaysia can consider allowing their employees fill up such a questionnaire or allow them to engage a medical professional or HR expert so that employees who are suffering from high levels of stress can seek advice from them. For future studies, researchers could consider studying the demographic factors such as age or family background that might affect human error in the manufacturing industry.

While working overtime could be good for the productivity of some companies, too much overtime can result in poor concentration. It is also unhealthy for the employees' personal lifestyle and affects their work-life balance. Although the Malaysian Employment Regulation sets a limit to overtime work which constitutes a total of 104 hours in any month, or an average of 4 hours a day, it may still be very exhausting for some manufacturing workers [37]. Employers in manufacturing SMEs should prioritise the employees' health rather than high productivity. Although high productivity might contribute to high profits, the consequences of workplace accidents and injuries can include high compensations for the employees or even their death. On the other hand, allowing employees to go home on time and report to work on time helps build a more positive work culture and healthier workplace. Besides, author recommended future studies to focus on more sample sizes aand consider qualitative data analysis or interview to obtain managerial perceptions on human error.

Authors' Contributions

J. A. Yeow contributed on the overall structure of the research paper and drafted the manuscript. P. K. Ng contributed on the literature review, analysis and conclusion. Y.

J. Ng contributed on the survey and data collection, and conclusion. All authors approved the final version of the manuscript.

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