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Human-Centric Approach in Smart Remanufacturing for End-Life-Vehicle (ELV)'s Stabilizer Bar

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ABSTRACT

This paper aims to develop a new recommended human-centric framework for the smart remanufacturing of End-Life-Vehicle (ELV)s stabilizer bars to enhance worker experiences. The human-centered method has been applied in various applications since its introduction. Still, there has been little consideration of worker experience challenges in developing the smart remanufacturing of ELV's stabilizer bar concept. Data were analyzed using a regression model to evaluate the six hypotheses to generate the human-centric model. According to the research, five aspects of the human-centric model strongly correlate with worker experience: emotional, cognitive, intellectual, confidence and trust. However, only one aspect, behaviour, did not significantly correlate with worker experience. As a result, the conceptual framework excludes the minor aspect of worker experience in human-centric design. Recognizing the importance of smart remanufacturing of ELV's stabilizer bar, this model is expected to be used as guidance to build a smart remanufacturing of ELV's stabilizer bar system that specifically responds to human needs.

1. Introduction

The booming automotive market, which has also led to an increase in the quantity of end-of-life vehicles (ELVs) that are no longer in use, perceives corporate responsibility and environmental consciousness as one of the roadmaps for vehicle manufacturers [1]. ELV management has changed from being a significant disadvantage to being a source of competitive equality and one of the most

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crucial factors in automotive aftersales [2]. Most vehicle manufacturers worldwide tend to implement the remanufacturing concept as one of the ELV management steps, which is essential for better environment and economic factors [3]. While the principle of remanufacturing is more acknowledged and applied in countries such as North America and Europe, numerous developing nations still have far to go before taking the forefront in global environmental sustainability [4]. Nevertheless, several Malaysian vehicle part manufacturers have altered their business models to include remanufacturing [5]. When it comes to technology, the majority of automotive industry players consider smart remanufacturing, particularly information and communications technology (ICT), which is evolving at a rapid pace these days with numerous disruptive technologies such as cloud computing, the Internet of Things (IoT), big data analytics, and artificial intelligence arriving daily [6]. Smart remanufacturing is the practice of utilizing and applying these criteria during the remanufacturing process [7]. These new technologies are entering remanufacturing processes and acting as crucial facilitators for the industry to tackle contemporary challenges, including increasingly individualized needs and improved quality [8]. Machines can perceive, act, and communicate with one another after being trained. These technologies also enable gathering and sharing real-time production data, which can subsequently be used to make informed decisions.

According to studies, 85% of the weight of remanufactured products can be obtained using components that operate similarly to new products but need less energy to manufacture [9]. According to Oeko [10], the ELVs Directive (2000/53/EC) helped and continues to help reduce residual waste from ELVs by ensuring that its component parts can be reused, repurposed, or recovered. As a result, the average weight of reuse and recycling shall not exceed 85% per vehicle and year. Components from used items are utilized in remanufacturing. As a result, purchasing raw materials is less expensive than producing new things. Remanufactured goods are thought to be produced for 35–65% less money [5, 10, 11], making them more accessible. Remanufacturers assert that their costs are 10% to 90% less than those of brand-new items, with the majority being about 50% less [15]. Remanufacturing is also anticipated to generate employment possibilities. An item that has been remanufactured uses 85% less energy than one that has been brand new. One of the automotive parts that can undergo remanufacturing is the stabilizer bar. The growing automotive industry mostly drives demand for stabilizer bars. The stabilizer bar is a crucial part of the construction and remanufacturing of any automobile because it increases vehicle safety by reducing body roll when making sharp turns or navigating rough terrain [3]. The Global Automotive Stabiliser Bar Market is anticipated to expand at a compound annual growth rate (CAGR) of 5.4% between 2022 and 2029 [16]. The rising labour cost was frequently a side effect of the growing demand for stabilizer bar production. The majority of businesses must manage the difficulty of a skilled workforce shortage. Due to increased industrial competition, skilled workers are hard to locate, hire and keep [17]. Most skilful workers need extra time to finish the production at the required time, which leads to a stressful working environment. These practices have led to unpleasant experiences for workers.

Realizing the importance of stabilizer bar parts in ELV management sectors, most automotive companies have made several efforts to provide sustainable stabilizer bar supply through remanufacturing [18], such as designing a new smart factory or re-designing existing stabilizer bar manufacturing factory for remanufacturing to be implemented. Further, considering the importance of smart manufacturing for stabilizer bar productions, the companies must ensure stabilizer bars are created or manufactured using modern infrastructure and services while also giving employees a stress-free and convenient work environment [19]. Designing a smart manufacturing stabilizer bar that considers the workers' requirements, settings, behaviours, and emotions is necessary in this situation. In order to build the new recommended human-centric model of smart manufacturing of stabilizer bars, this study aims to determine the characteristics that influence employees' experiences handling smart remanufacturing of stabilizer bars. As a result, rather than covering the experience of all workers in the manufacturing environment, this study focuses on worker experience and smart remanufacturing of stabilizer bars. The next sub-topic will describe the literature review on human-centered aspects, followed by the research design, analysis, and conclusions. The results of this investigation will be outlined in the conclusion.

2. Human Centric worker experiences

This section offers essential information encouraging the researcher to develop a smartly remanufactured stabilizer bar system. As a result, this section presents the current research on smart remanufacturing technologies and features of worker experiences at the manufacturing site. There are numerous studies on intelligent remanufacturing systems. For example, J. Alieva [20] investigated how intelligent remanufacturing may save production time as production increased but did not address the human component. Valentina *et al.* [21] looked at how to monitor the remanufacturing system while including IoT and Machine Learning (ML). The researchers focused on the technical and technological elements of the proposed system, which was evaluated for car manufacture in South Korea [3]. They did not construct human-centric features, however, because they did not assess the impact of these traits on improving workers' experiences by instilling a sense of human centricity [4]. Although attempts have been made to develop smart remanufacturing systems for automotive systems, these systems have not addressed issues about worker behaviour on the production site and their satisfaction with the method utilized by factory authorities [22].

Kalinowski [23] stated the dependability and unpredictability of human behavior are influenced by the interaction between the workforce and the many supporting technologies of the 4.0 paradigm, which may significantly impact the requirements for quality, safety, and productivity. An employee sample from Polish automotive firms was polled by Kalinowski [23] to learn more about their knowledge, openness to change, desire to become more competent, level of faith in technology, and level of technology aversion. In the opinion of Nallaluthan *et al.* [24], it is critical to provide suitable conditions for human work, approaches, and actions in cognitive, emotional, and psychic aspects because employees in this intelligent environment will require less physical effort, more effective internal and external communication by artificial intelligence, companies, and people, decision-making processes based on sets of criteria, tools, and data, and other positive implications. Lee *et al.* [8] conducted additional research on intralogistics employees' work patterns for the smart industrial service Intralogistics 4.0. They concluded that worker contact and digitalization experience were inadequate. Even though they identified a component that affects employee experience, this research was conducted for the general manufacturing industry rather than the automotive industry, and employee behaviour in general smart manufacturing may vary from that of employee behaviour in the production of automobile bars. Additionally, they had little interest in producing stabilizing bars intelligently. The design, manufacture, analysis, and testing of a customizable anti-roll bar system for a formula student race car are covered by Suhaimin *et al.* [9] on smart manufacturing of stabilizer bars. The study, however, does not address the role of human-centric factors in advancing smart manufacturing.

This study aims to investigate the factors influencing the employee experience using the Human Centric Model of Smart Manufacturing of stabilizer bars. The factors influencing employees' experiences are determined using the existing literature and the researcher's point of view. Figure 1 shows how the conceptual framework was the driving force behind the study's empirical data collection. The process/service of the smart manufacturing system, the facilities that the system uses, and the people are the three variables that are taken into consideration in the smart production of stabilizer bars. Figure 1 illustrates the six constructs [4, 11, 14, 16, 17, 22, 23] that influence employee experience: knowledge, cognition, behavior, emotions, confidence, and trust. They are known as independent variables. Employee behaviour, or the dependent variable, has four dimensions: i) dependability, ii) safety, iii) zeal, and iv) contentment. The study's testable hypotheses are stated in Table 1 and are based on the conceptual framework represented in Figure 1.

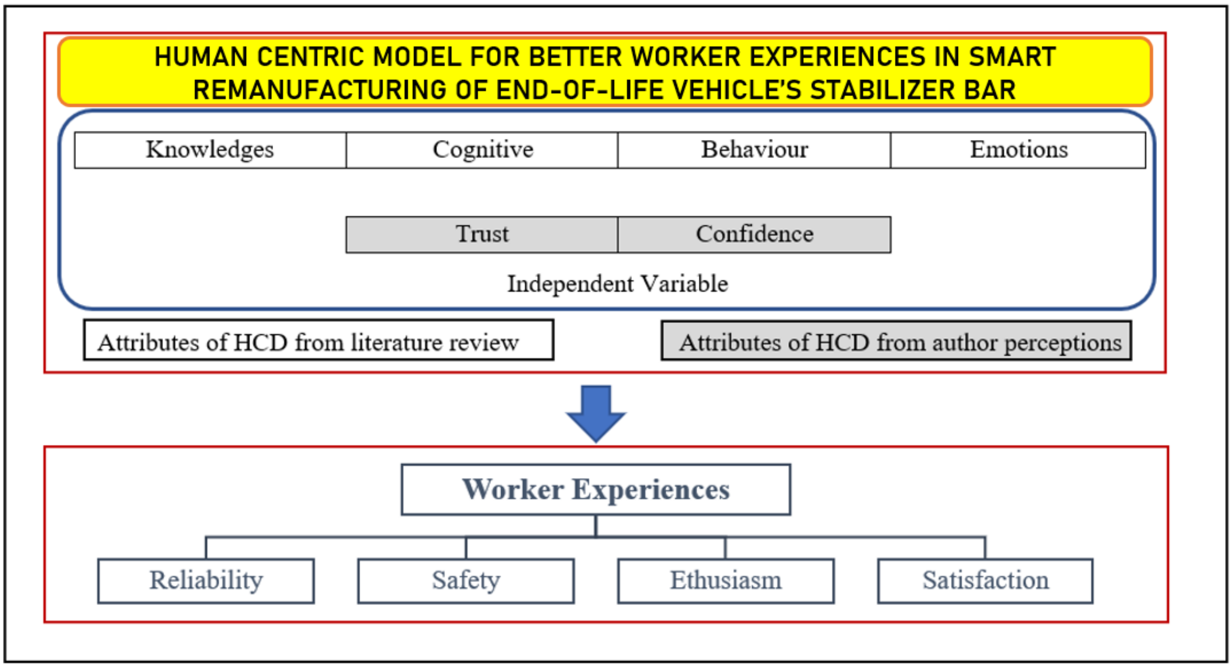

Fig. 1. Conceptual framework

Table 1
Hyphothesis

No	Description
H1	The knowledge attribute has a significant relationship to worker experience
H2	The cognitive attribute has a significant relationship to worker experience
H3	The behaviour attribute has a significant relationship to worker experience
H4	The emotion attribute has a significant relationship to worker experience
H5	The trust attribute has a significant relationship to worker experience
H6	The confidence attribute has a significant relationship to worker experience

3. Methodology

To determine the factors that closely link with worker experiences in stabilizer bar smart manufacturing, the study used a quantitative research method that involved collecting empirical data and objectively analyzing the results. Six hypotheses were explored to determine whether there was a substantial correlation between the characteristics and the worker's experience. A questionnaire was used to gather information for this survey study project. A questionnaire that allows for speedy dialogue with respondents can save time and money, according to Mhlanga [25]. According to the phases of questionnaire design, the questionnaire was divided into three sections: Section A contains the demographic profile, Section B contains the independent variable with six attributes, and Section C contains the dependent variable with worker experience. Section A is divided into five categories: gender, age, educational attainment, educational attainment, and employment experience. Section B comprises six components: knowledge, cognition, behaviour, emotion, trust, and confidence. Section C concludes with a discussion of worker experience. The components for each of the six constructions are listed in Appendix 1. For concept validity, the questionnaire items are derived from [20]. Sections B and C questions are scored using an objective Likert Scale ranging from 1 (totally disagree) to 5 (absolutely agree). The face's validity had already been established. A pilot test was also conducted to evaluate the questionnaire's validity. To gauge the questionnaire's dependability, a modified version was given to responders from a sample representative of the intended audience. The trial was carried out in a Bangi, Selangor, Malaysia facility that produces stabilizer bars. In this instance, 150 workers received the survey form. The distribution of the questionnaire was done using a stratified random sample method. Paper surveys were used to spread the strategy. People who answered the questions on paper were given a copy of the survey and a pen. Data were gathered by the researcher for four months and examined using descriptive and inferential statistical analysis in SPSS version 22.

4.0 Result and Discussion

4.1 Demographic Analysis

The data for this study came from 150 respondents, and the sample profile is shown below. The demographic profile of the respondents, including gender, age, education, citizenship, and years of work experience, is shown in Table 2. With 76% of respondents being men and 24% being women, the sample showed that men outnumber women in gender. The largest age range is between the ages of 21 and 40 (50%) followed by the ages of 41 to 60 (21%), and those under the age of 20 (24%). The lowest percentage (5% of those over 60) is found in this group. The sample comprises well-educated persons, with 21% holding a bachelor's degree or more, 31% holding a diploma, and 48% claiming other academic credentials. Furthermore, Malaysian nationals comprise 61% of the workforce, while international employees comprise 39%. Finally, 63% of respondents, or the majority, had 5-10 years of work experience. Then, 19% of the workers have ten years or more working experience in the industry. Lastly, 18% of the respondents only have working experience below five years.

Table 2
Demographic Profile of Respondent

Demographic	Classification	Frequency	(%)
Gender	Male	115	76
	Female	35	24
Age	Below 21 years	35	24
	21 years old – 40 years old	76	50
	41 years old – 60 years old	31	21
	Above 60 years old	8	5
Education	SPM and below	73	48
	Diploma	47	31
	Bachelor and above	30	21
Citizenship	Malaysia Citizen	91	61
	Foreign Worker	59	39
Working experiences	Below 5 years of working experiences	27	18
	5-10 years of working experiences	94	63
	Above 10 years of working experiences	29	19

4.2 Reliability Analysis

Table 3 displays the dependability statistics based on the 30 items in the researcher's questionnaire. The Cronbach's Alpha coefficient of 0.944 in Table 6 indicates that all of the questionnaire's items are reliable.

Table 3
Reliability Test of The Questionnaire

Reliability Statistic	
Cronbach's Alpha	N of items
0.944	30

4.3 Correlation Analysis

The hypothesis was tested by evaluating the correlation strength between the independent and dependent variables using Pearson's Correlation. As shown in Table 4, we use the correlation coefficient proposed by [22] for this inquiry.

Table 4
Summary of Measurement of Strength based on the Correlation Coefficient

Correlation Coefficient	Strength of Association between Variables
+-0 to +-0.2	Very Weak
+-0.2 to +-0.4	Weak
+-0.4 to +-0.6	Moderate
+-0.6 to +-0.8	Strong
+-0.8 to +-1.0	Very Strong

Pearson's Correlation analysis in Table 5 shows the correlation strength between an independent variable (knowledge, cognition, behaviour, emotions, confidence, and trust) and a dependent variable (worker experience). Table 5 shows a 1% significant degree of relationship between knowledge and passenger experience, implying a link between the two. Furthermore, 0.476 indicates a fairly good relationship between worker experiences and knowledge. Then, there is a 1% significant relationship between cognitive capacity and labour experience. The value of 0.453, however, shows a modestly positive correlation. In other words, worker experience and cognition have a mediocrely beneficial association. This demonstrates that people who have been passengers favour the medium ergonomic. According to Table 5, the link between behaviour and work experience has a 1% significant level. Therefore, the value of 0.367 denotes a positive link. This score shows a moderate relationship between passenger experience and behaviour. According to Table 5, the correlation between employee experiences and emotion is 1% significant. Overall, 0.678 implies a moderately decent relationship. In other words, this score represents both a high level of reaction behaviour and a high level of passenger experience. The relationship between trust and worker experiences, as illustrated in Table 8, demonstrates a strong link. This reflects the respondents' high degree of trust and employee experience. According to Table 5, the relationship between cognitive capacity and job experience has a 1% significance level. Given this, a score of 0.545 indicates as moderate .

Table 5
Pearson's Correlation Analysis

	Worker experiences (w)	Knowledge (k)	Cognitive (cg)	Behaviour (b)	Emotion (e)	Trust (t)	Confidence (cf)
Worker experiences (w)	1						
Knowledge (k)	0.476**	1					
Cognitive (cg)	0.453**	0.267**	1				
Behaviour (b)	0.467**	0.483**	0.678**	1			
Emotion (e)	0.678**	0.544**	0.378**	0.142**	1		
Trust (t)	0.667**	0.168**	0.245**	0.654**	0.786**	1	
Confidence (cf)	0.545**	0.567**	0.432**	0.344**	0.855**	0.564 **	1

** Correlation is significant at the 0.01 level (2-tailed)

4.4 Regression Analysis

Regression analysis was also performed to determine the general association between the components of the human-centric model and the passenger experience. Table 6 outlines the six independent factors that the researcher used to identify the element of the human-centric model that could influence the adoption of smart manufacturing for stabilizer bars. Worker experience is the dependent variable, while the six independent variables are knowledge, cognitive, behaviour, emotion, trust, and confidence. Because all variables were entered, none were deleted.

Table 6
The factor of the human-centric model influences on worker's experience

Model	Variable Entered	Variable Removed	Method
1	k, cg, b, e, t, cf	none	Enter

a. Dependent Variable: Worker experiences (we)
b. All request variables: k, cg, b, e, t, cf

The regression analysis aims to determine how well the regression model fits the data from the investigation. Three analyses of variable anticipated values were conducted, and they are as follows: The first three components are the Model Summary (R-value), ANOVA variable (p-value), and Regression Coefficient Analysis (hypothesis outcome). Table 10a displays the Model Summary result. As demonstrated in Table 7, there is a strong association with an R-value of 0.825 between worker experience at the Bangi stabilizer bar factory's smart manufacturing and the variables of the human-centric model. As a result, the R-value indicates a high association between the components and worker experience. According to Table 8, the ANOVA variable's significant p-value is 0.001, which is less than the threshold of 0.05. Hence, these factors significantly affect worker experience. The outcomes of multiple regression for the six provided hypotheses are finally shown in Table 9. Table 9 demonstrates that, except for the behaviour variable factor (0.879), which is more than 0.05, five of the six independent variables have p-values less than 0.05, showing that these variables are significant. This demonstrates the acceptance of the idea that knowledge, cognitive ability, emotion, trust, and confidence are correlated with worker experience.

Table 7
Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0.825	0.662	0.645	0.23429	1.821

Table 8
ANOVA Analysis

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	6.789	5	1.137	23.699	0.001
Residual	3.896	72	0.053		
Total	10.685	77			

Table 9
Regression Coefficient Analysis

	Unstandardized Coefficient		Standardized Coefficient	T	Sig.
	B	Std. Error	Beta	3.842	0.001
Constant	0.933	0.326		3.123	0.005
Knowledge	0.237	0.178	0.243	1.465	0.003
Cognitive	0.198	0.062	0.176	4.231	0.065
Emotion	2.256	0.087	0.558	3.118	0.000
Behaviour	0.058	0.077	0.045	0.210	0.879
Trust	0.264	0.049	0.285	2.478	0.007
Confidence	0.273	0.063	0.369	2.943	0.004
Predictor: (constant), k, cg, e, b, t, cf		Dependent: W			

The summary of this study’s hypothesis testing is shown in Table 10. Table 10 reveals that six hypotheses were approved, and one was rejected. The most significant link between the mood dimension and worker experience has been discovered to support the accepted hypothesis (0.000, p 0.05). The knowledge factor (0.003, p 0.05), confidence parameter (0.004, p 0.05), trust parameter (0.007, p 0.05), and cognition parameter (0.065, p 0.05) are revealed to have the strongest relationships with worker experience. However, the behaviour parameter is rejected (0.879, p>0.05), indicating no meaningful association between it and worker experience.

In Table 10, it is shown that Hypothesis H3 is rejected at 0.879, which denotes a p-value higher than 0.05. Thus, the worker has no connection to the behaviour parameter H0. The major study’s findings allow us to conclude that although smart manufacturing in stabilizer bars negatively correlates with behaviour, it does not impact worker experience. The statistical result of Hypothesis H2 is accepted, as shown in Table 10 because the p-value is smaller than (p-value=0.000). H2 is a cognitive characteristic that positively corresponds with employee experiences. This is due to the straightforward, easy-to-understand handbook for smart manufacturing [23]. The impact of smart manufacturing utilizing a human-centric paradigm and worker happiness are strongly correlated, as shown in Table 10. This is because H1 and this hypothesis have a favourable association, and the p-value is less than 0.005. It’s critical to handle employees’ basic manufacturing knowledge effectively: This promotes innovation, makes it simpler to put it into effect, facilitates decision-making, and reduces personnel turnover and attrition. Furthermore, it helps prevent information loss, particularly among geographically dispersed workforces.

Table 10
Summary of Hypothesis Testing of Analysis

No	Description	p-Value, sig.	Decision
H1	The knowledge attribute has a significant relationship to worker experience	P < 0.05; 0.001	Accepted
H2	The cognitive attribute has a significant relationship to worker experience	P < 0.05; 0.005	Accepted
H3	The behaviour attribute has a significant relationship to worker experience	P > 0.05; 0.879	Rejected
H4	The emotion attribute has a significant relationship to worker experience	P < 0.05; 0.000	Accepted
H5	The trust attribute has a significant relationship to worker experience	P < 0.05; 0.008	Accepted
H6	The confidence attribute has a significant relationship to worker experience	P < 0.05; 0.009	Accepted

The Bangi smart factory, which produces car stabilizer bars, was affected by the emotional component of H4 regarding how the employees felt. The use of emotional needs and feelings has greatly impacted service design and development. This demonstrates how the workers employed the smart manufacturing system in a lovely, pleasant, contented, tidy, reliable, happy, appealing, and contemporary manner. Hypothesis H5 is accepted for this inquiry since, as shown in Table 10, it has a favourable association with worker experience. The p-value of 0.008, which is less, does not meet the (p-value 0.050) standard.

Furthermore, Hypothesis H6 is accepted, indicating that the confidence parameter is substantially associated with the influence of the human-centric model of smart manufacturing of stabilizer bars on worker experience. [25] suggests that the trust and confidence of workers adopting smart manufacturing systems may be strengthened. The worker's confidence that a smart manufacturing system is safe and usable by everyone. Overall, there is a high correlation between the emotion parameter and worker experience. Based on all the findings, Figure 2 presents the latest human-centred design model revised for a smart production system of stabilizer bars.

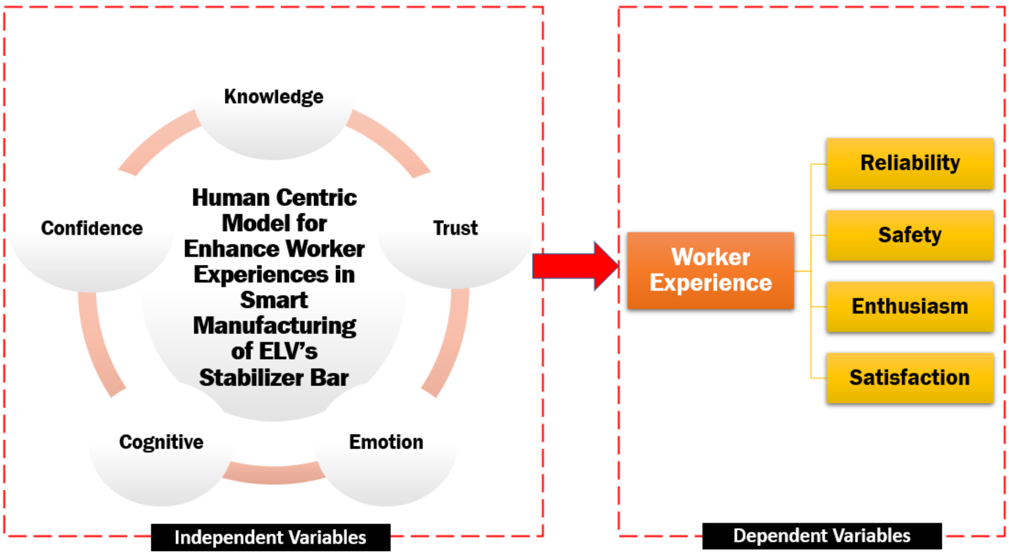

Fig. 2. Revised Model of Human-Centric design for smart remanufacturing of ELV's stabilizer bars

5.0 Conclusions

Smart remanufacturing is a technological strategy that uses Internet-connected devices to monitor the remanufacturing process and data analytics to boost efficiency. A worker's assessment of their task success is known as their "worker experience." This research aims to develop an intelligent, human-centered ELV stabilizer bar system. This study examined how six human elements relate to how well the system works for workers to achieve this. A total of 150 system users were surveyed at the stabilizer bar manufacturing plant in Bangi, Selangor. Data were evaluated using a regression model to test the six assumptions to build the human-centric mode. According to the study, five dimensions of the human-centric paradigm are closely related to the employee experience: 1) emotional, 2) cognitive, 3) knowledge, 4) confidence, and 5) trust. However, only one factor, behaviours, did not significantly correlate with worker experience. As a result, the researcher dismissed employee experience and human-centric design as unimportant components of the conceptual framework. The limitation of this study is that it only looks at stabilizer bar remanufacturing for mid-sized autos. Even if the respondents are eligible for this type of study, this study does not separate them into different groups, such as illiterate or literate. As a result, this study will gather more data, such as the factors that impact workers' experiences with various levels of literacy during smart remanufacturing at the stabilizer bar facility. Finally, the results support the proposed paradigm for a stabilizer bar production system that is human-centric and intelligent. By minimizing worker workload through clever remanufacturing, the study influences the impact of the worker experience. According to statistical analysis, employee experience is positively correlated with human centricity. The smart manufacturer of stabilizer bars provides a positive working environment for employees by using human-centred stabilizer bar automated machining. Given the importance of worker experiences in smart remanufacturing systems, this model is expected to be used as guidance to design a smart remanufacturing stabilizer bar system that directly addresses human emotions and knowledge.

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