Evaluation of the SM-8018 Shima Ergono Wheelchair Product Prototype Design Based on Quality of Life and Ergonomic Function Deployment

Heri Setiawan
Industrial Engineering Study Program
Science and Technology Faculty, Musi Charitas Catholic University
Bangau Street No. 60 Palembang, South Sumatera, Indonesia
heri_setiawan@ukmc.ac.id

Micheline Rinamurti
Management Study Program
Business and Accounting Faculty, Musi Charitas Catholic University
Bangau Street No. 60 Palembang, South Sumatera, Indonesia
rinamurti@ukmc.ac.id

Abstract

This research aims to evaluate the comfort of the product prototype of the SM-8018 Shima Ergono Wheelchair produced by PT SPU. The ergonomic approach method is reviewed from UQoL and EFD. A survey of 30 respondents with anthropometric data on the 5th, 50th, and 95th percentiles, the NBM questionnaire, fatigue, boredom, satisfaction tested with t independent samples at a significance level of 5% ($\alpha = 0.05$), and VoC data for wheelchair standard attributes manual for obtaining HoE consists of; Effective, Comfortable, Safe, Healthy, and Efficient aspects. The results of the study found that anthropometry was appropriate, redesign was needed on the seat, back and head rests, musculoskeletal complaints and fatigue were still there, especially for thrusters of 52.05% and 50.20%, a decrease in boredom and satisfaction by 17.52% and 12.85% ($p < 0.05$). The order of priority of the specification target based on the HoE is; Adjustable push handle & Ergonomic Factor, the stand does not bend easily when occupied, the backrest and height are anthropometrically adjusted, and need to add a headrest, the stability of the front tire when going through obstacles in the area of incline, derivation, and slope remains stable.

Keywords
SM-8018 Shima Ergono Wheelchair Prototype, UQoL, and EFD.

1. Introduction
A wheelchair is a means of assisting people with disabilities or leg injuries to be able to move from one place to another, either on a flat place or from a low place to a higher place. It is often also meant that wheelchairs are used to improve mobility for people with disabilities such as: people with physical disabilities especially those with leg disabilities, hospital patients who are not allowed to do a lot of physical activity, the elderly, and other people who have a high risk of injury, when walking alone. In general, wheelchairs are divided into two types, namely a conventional wheelchair and a motorpowered wheelchair. Conventional types can be divided into standard wheelchairs and sport wheelchairs. Meanwhile, powered whellchairs are divided into several models, such as: traditional, platform, and round based models. Functionally, the platform model wheelchair is perfect for wheelchair users without a guide. This wheelchair is driven by a motor (battery) and controlled easily via a joy stick control, it can move forward and turn, but it is heavier than a standard wheelchair. Because the controller is automatic, the price of platform model wheelchairs is very expensive and is still quite rare in Indonesia. The new product recently launched by PT SPU (PT Shima Prima Utama) is the SM-8018 Shima Ergono Wheelchair. This type of wheelchair produced

by PT SPU is the type of manual wheelchair that is most widely used by most of its users. The use of the SM-8018 Shima Ergono Wheelchair is manually pushed by another person.

2. Literature Review

The quality of life of users of the wheelchair type or User Quality of Life (UQoL), which is a measure of health, safety, comfort and satisfaction felt by users or potential users of the SM-8018 wheelchair Shima Ergono Wheelchai in carrying out daily activities Quality of life of users or potential users of the SM-8018 Shima Ergono Wheelchair as a simultaneous and continuous effort by creating a sense of security, health and satisfaction in daily activities. Cascio (2006) and Setiawan (2012) state that UQoL is a set of perceptions of user respondents or potential users of the SM-8018 Shima Ergono Wheelchair regarding health, a sense of security and comfort in daily activities, satisfaction with daily activities and conditions to grow and develop as human; and others. Ergonomic perspective in UQoL related to daily activities of users or potential users of the SM-8018 Shima Ergono Wheelchair is an elaboration of several criteria, including; Musculuskeletal complaints, fatigue, boredom, comfort, and satisfaction in daily activities. The musculoskeletal system is a skeletal muscle system or muscles attached to bones consisting of cross-fiber muscles that are voluntary in nature. Skeletal muscle groups, based on their location, consist of muscle groups in the neck, back, chest, shoulders, upper arms, forearms, buttocks, pelvic floor, upper thighs, calves and legs. Musculoskeletal complaints are caused by psychosocial, individual, workplace, and work organizational factors (Izumi, 2008), do not occur immediately after exposure to risk factors, but there is an accumulation of disturbances during a certain period (Coleman, 2008). If the muscle receives static loads repeatedly and for a long time, it can cause complaints in the form of damage to joints, ligaments and tendons. Complaints to this damage are usually termed musculoskeletal complaints or injuries to the musculoskeletal system (Grandjean, 2007). Complaints in the musculoskeletal system are caused by: (1) carrying out lifting weights that are too heavy; (2) certain repetitive movements; (3) posture sitting, standing when doing activities; (4) using the wrong lifting technique; and (5) work pressure. Some of the ergonomic measurement tools that are often used to measure musculoskeletal complaints, one of which is: subjective measurements, using diaries, interviews and questionnaires to assess musculoskeletal complaints in workers using the Nordic Body Map (NBM) questionnaire (Ercan and Erdinc, 2006).

Fatigue is a natural sign of the body to get some rest, usually associated with working or doing daily activities for a long time. Symptoms of work fatigue in industry or after carrying out daily activities: (1) feeling tired; (2) physiological changes in the body such as nerves and muscles not functioning properly; and (3) decreased work capacity (Barnes, 1980). Fatigue from work activities depends on: (1) hours or duration of activity; (2) the number, location and length of rest periods; (3) physical environmental conditions where you do your activities; and (4) the activity itself. Subjectively fatigue can be measured using a 30 items of rating scale questionnaire issued by the Japan Association of Industrial and Health (JAIH). This questionnaire consists of 3 categories, namely: weakened activity (items 1-10), decreased motivation (11-20) and physical exhaustion (21-30).

Boredom is a situation with low, repetitive stimuli or with low physical and mental demands which will also cause a small stimulus in the area of consciousness in the human brain. Grandjean (2007) in Setiawan (2017). Consequently, the limbic system will be affected and the reaction of the organism as a whole will decrease. According to Kroemer (2009), the characteristics of the work environment received by workers are monotonous and varied. The factors that cause boredom are: (1) less attractive work; (2) lack of motivation to work; (3) the job does not require high skills; (4) work speed is too slow; (5) the work environment is unattractive or gloomy; (6) repetitive or repetitive types of work; (7) short duty cycle; (8) lack of opportunities for the body to move; (9) hot conditions; (10) lack of contact with fellow employees; and (11) the ability of employees is not channeled (Pulat, 1992; Grandjean, 2007). Furthermore, Setiawan (2019a) reported that the workers' boredom in rubber factories can be reduced by setting active breaks between working hours and setting music during work.

There are 20 things that indicate a person's complete job satisfaction in the company (Minnesota Satisfaction Questionnaire/MSQ), namely: ability utilization, achievement, activity, skills, authority, company policies, rewards, relationships with coworkers, creativity, independence, value- values, recognition, responsibility, security, social services, social status, relationships with superiors, superior technical abilities, variations, and working conditions (Syamsi 2004). Based on these 20 terms, a MSQ was developed. The feeling of being satisfied or not depends on the level of expectation and the perceived level of service received. If the gap is negative, meaning that the level of perception is higher than the level of expectation, the worker will feel disappointed, and vice versa. In this study, job satisfaction was measured using the MSQ questionnaire with a 5 Likert scale from very dissatisfied to very satisfied scores.

Ergonomic Function Deployment (EFD) is a development of Quality Function Deployment (QFD) (Ulrich & Eppinger, 2001) by adding a new relationship between consumer desires and ergonomic aspects of the product. This relationship will complement the form of the House of Quality matrix which also translates into the desired ergonomic aspects. The House of Quality matrix used in EFD was developed into the House of Ergonomics (Astutik, 2015).

3. Methods

This research was conducted at PT SPU. PT SPU is a company engaged in the medical aid industry, such as: wheelchairs, canes, crutches and walkers. This company produces approximately 19,000 medical aids every month. This company is located at Lorong Sebatok Jl. Taman Kenten No.76A, Duku, Kecamatan Ilir Timur II, Palembang City, South Sumatera 30163. This company was chosen as the research location because the researcher is consulting PT SPU to conduct research and development of a product comfort/ergonomics perspective for a new product type, namely the SM-8018 Shima Ergono Wheelchair Wheelchair. Parts of a wheelchair consist of; a set of wheels at the back and a set of wheels at the front. This design makes the SM-8018 Shima Ergono Wheelchair stable and easy to move forward and backward and turn. The SM-8018 Shima Ergono Wheelchair is included in the manual wheelchair which is lightweight and folds up to carry in car transportation. This research flow is based on the company's request to provide consultations, surveys and research related to the aspect of comfort / ergonomics evaluation of the development of the SM-8018 Shima Ergono Wheelchair prototype design before it is mass produced. Problem identification and formulation focus on manual wheelchair standards and aspects of product design that are ergonomic and relevant references. The data collected from respondents (users and potential wheelchair users) are; anthropometric data, NBM questionnaire that represents any musculoskeletal disorders or complaints. Fatigue questionnaire, boredom questionnaire, respondent satisfaction questionnaire, and Voice of Customer (VoC) interview results with respondents as a representation of EFD. The data required in the VoC are the standard attributes of a manual wheelchair; functional performance (Effective), seat and postural support (Comfortable), strength, endurance and safety (Safe), musculoskeletal, fatigue, boredom, and satisfaction (Healthy), and economical-care-raw materials (Efficient). after the data is tested statistically using validity and reliability tests then processing the data with the implementation of the EFD method which includes; a) identification of the respondent's needs, b) determining the level of interest of the respondent, c) measuring the level of respondent satisfaction, d) determining the target value, e) determining the repair ratio, f) determining the selling point, g) determining the raw weight, h) determining the normalized raw weight , i) preparation of technical interests, and j) compilation of the house of ergonomics (HoE). Anthropimetric data calculating the dimensions of the respondent's body by looking for the 5th, 50, and 95th percentiles. Test for normality of User Quality of Life (UQoL) data on (a) NBM data / musculoskeletal complaints, (b) fatigue, (c) boredom, (d) comfort, and (e) satisfaction with paired t test (t independent samples) at a significance level of 5% ($\alpha = 0.05$). Evaluation of the development of UQoL and EFD-based product prototype designs was conducted on 30 respondents

4. Data Collection

A wheelchair is a tool for people with leg disabilities to be able to move from one place to another, either on a flat place or from a low place to a higher place. Wheelchairs are also used to improve mobility for people with disabilities such as: physically disabled people, hospital patients, the elderly (seniors), and people who are at high risk of injury, when walking alone (Batan, 2006). In general, wheelchairs are divided into two types, namely a conventional wheelchair and a moto powered wheelchair. A picture of a manual wheelchair and its parts, is shown in Figure 1.

(a) (b)

Figure 1. a) Manual wheelchairs and their parts (Cook, 2015), and b) Dimensions of Wheelchairs SM-8018 Shima Ergono Wheelchair Production Result of PT SPU

SM-8018 Shima Ergono Wheelchair with product specifications: Contruction: Steel Pipe, Dimension: 1035mm (L) x 630mm (W) x 895mm (H), Steel Finishing: Epoxy Powder Coating, Front heel: 6" Solid Tire, Rear Wheel: 12 "Solid Tire, Upholstery: Fabric Cushion, and Footplate: Plastic Black. SM-8018 Ergono Wheelchair when operated is presented in Figure 2.

Figure 2. The SM-8018 Shima Ergono Wheelchair When Operated

Here is House of Ergonomic evaluation of the development of a wheelchair product prototype design is presented in Figure 3.

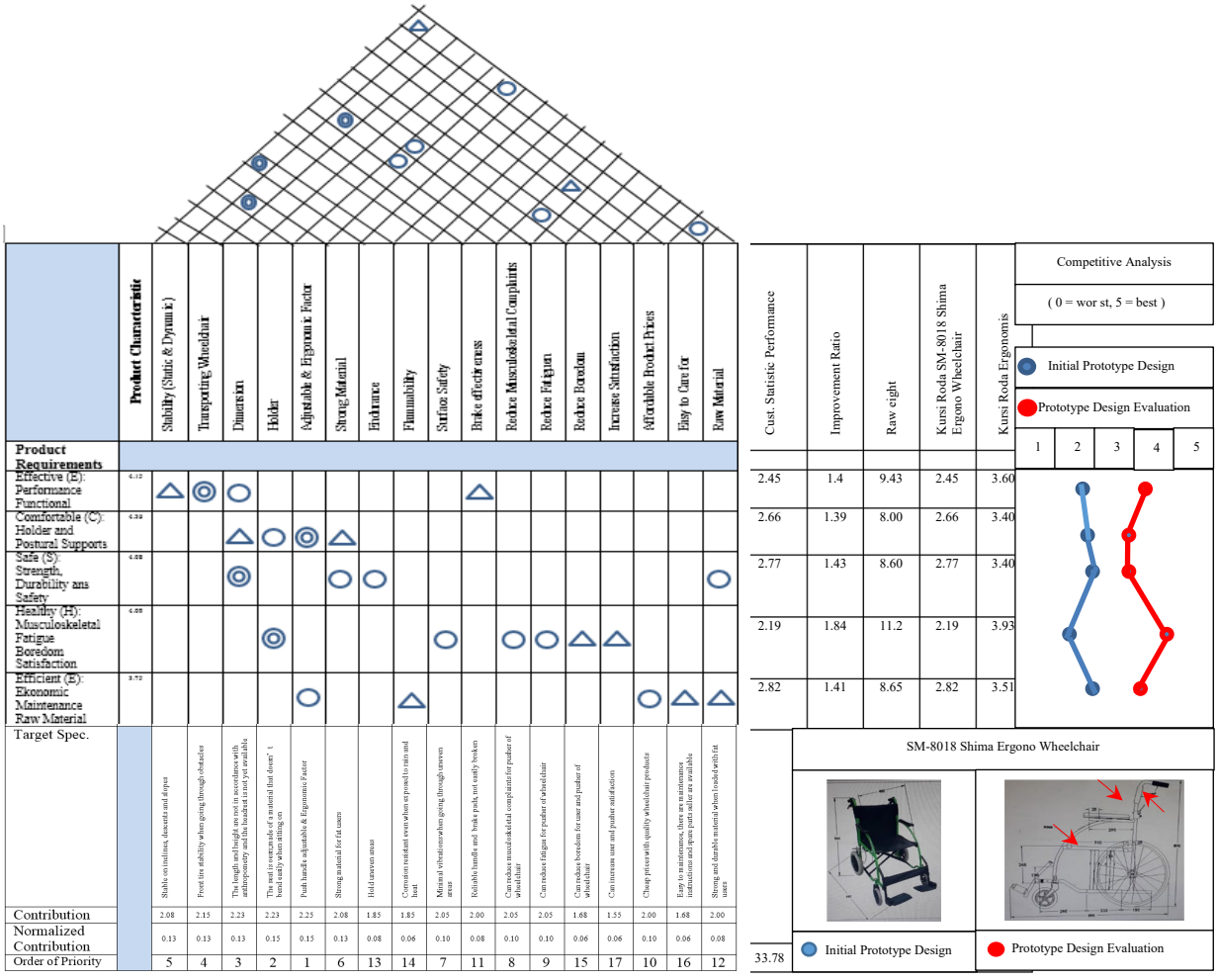

Figure 3. House of Ergonomic of the SM-8018 Shima Ergono Wheelchair Protoype Product

Evaluation of the of the SM-8018 Shima Ergono Wheelchair product design with reference to the comfort / ergonomics aspect with the ECSHE variable (Setiawan, 2019b) and the Indonesian National Standard Design (RSNI) framework for manual wheelchairs (Pratiwi, et.al. 2018) with conditions standards of safety, security, health, environment, development of science and technology as well as experience, current and future developments to get the maximum benefit (PP No. 102 of 2000 and UU No. 20 of 2014). Recapitulation of ECSHE variables, attributes and evaluation of wheelchair parts can be seen in Table 1.

Table 1. Recapitulation of Respondents Answers to the ECSHE Variable Attributes and Evaluation of Wheelchair Parts

Variable	Attribute	Wheelchair Parts	Wheelchair Evaluation
Effective (E)	Performance Functional	**Stability** (Static & Dynamic)	When in static condition it is good, but in a dynamic/mobile system it is still less statile if the user's body weight is overweighed.
		Transporting wheelchair (easy to move from-to, easy to operate, easy to carry a wheelchair)	It is good, but the front tire still rotates, turns and stops on its own if it goes through a small obstacle.
Comfortable (C)	Holder and Postural supports	**Dimensions** (Maximum length, width, total height, seat height, seat width from the ground, armrest height from the seat, seat length, backrest height, wheel chair maximum weight, adjusting the antropometry of Indonesian Society)	It is good, the height of the backrest is not good, it should be up to the head/headrest. The postural back of the chair is not ergonomic less tall and less titled back.
		Holder (Seat type, seat cushion, seat material, seat cushion material)	The seat cushion is not thick enough, it still curves if you sit on it so that the buttocks hurt the seat cushion.
		Adjustable and Ergonomic Factor (Beckrest, footrest, armrest, rear wheels, push handle)	Not good, especially in the less high beckrest (there is a headrest), the push handle has not been adjusted so that it makes cramps ache and tired of pushing.
Safe (S)	Strength, Durability and Safety	**Strong material** (Hard frame material)	Already well
		Endurance (Chair framei, push handle)	It's good, it still vibrates if the user is fat, the push handle is not adjustable.
		Flammability (Not flammable, Corrosion resistant)	Already well
		Surface safety (Flat surface, tire cover, have reflective stickers)	Already well
		Brake effectiveness (Stopped on the descent, did not come off suddenly)	Not good for the downhill, incline, and sloping road conditions.
Healthy (H)	Musculoskeletal	**Reduce musculoskeletal complaints**	There are still musculoskeletal complaints
	Fatigue	**Reduces fatigue**	Tired of pushing especially the push handle
	Boredom	**Reduces boredom**	It can reduce boredom
	Satisfaction	**Increase satisfaction**	Not yet satisfied
Efficient (E)	Economic	**Affordable product prices**	Prices can be pressed again
	Maintenance	**Easy to care for**	Already well
	Raw Material	**Raw material are strong and durable**	The frame still feels fragile if the user is fat. There are spare parts that break easily (brake pads)

5. Results and Discussion

From the results of the NBM questionnaire, the results were: a) judging from the side of musculosketal complaints, namely 92% pain in the back and buttocks (bottom), 100% pain in the push handle for thrusters, 45% pain in the neck and head, 35% pain in the leg, footrest-height polypeal not yet ergonomic.

The dimensions of the respondent's body or anthropometry used as a reference in evaluating the development of the SM-8018 Shima Ergono Wheelchair prototype design which were analyzed at the 5th, 50th, and 95th percentiles are still in accordance with Indonesian anthropometry, only the seat and backrest and the head are still needs to be repaired, size and postural. Related to these findings, Sutajaya (2018) states that in designing work tools and workspaces that

refer to user anthropometry, it is necessary to consider: (a) the high and low demands on muscle loads during activity, (b) the level of danger caused when doing activities by using certain work tools and in certain workspaces, (c) the location of the greatest load when lifting and transporting loads, operating work tools, sitting in a work chair, working at a work table and others, (d) work position when doing activities (sitting, standing, squatting, half squatting, sitting cross-legged, combination), (e) work attitude (natural or unnatural), (f) the nature of the work is static or dynamic as seen from the muscle contraction that occurs at the time perform activities, (g) possible variations in work positions and postures, (h) body movement patterns associated with the limitations of joint motion, (i) length of work by using force ga physical or muscular, (j) the level of precision or precision desired, and (k) the organs that are directly involved with the components of the tool.

Musculoskeletal complaints of respondents used as a reference in evaluating the development of the SM-8018 Shima Ergono Wheelchair product prototype increased, especially for wheelchair pushers, significantly 52.05% ($p < 0.05$) when viewed from the difference between musculoskeletal complaints before and after the activity. It occurs as a result of changes in isometric (static) to isotonic (dynamic) contraction which can be done through changes in working conditions. In connection with these findings, Pratama and Setiawan (2020) states that improving working conditions so that they become ergonomic is indeed very necessary so that workers avoid muscle complaints, as a result of inappropriate technology transfer. In this case an unnatural work attitude can act as a cause for the emergence of various complaints in the skeletal muscle system. To overcome this problem, it is necessary to implement ergonomic concepts that are studied in the development of wheelchair product designs related to the criteria for ideal posture in carrying out an activity or job. These criteria are: (a) the muscles that work statically are very few, (b) the task is carried out using the hands easily and naturally, (c) relatively little muscular effort can be maintained, (d) changes in work attitude or dynamic is better than relaxed static work attitude, (e) relaxed static work attitude is better than tense static work attitude. These findings are also in accordance with the opinion of Pheasant (1991) in Setiawan (2019b) which states that improving working conditions in dealing with posture during activities / work should refer to the principles: (a) preventing forward inclination of the neck and head, (b) preventing forward inclination of the body, (c) prevent the use of the upper limb in a raised state, (d) prevent rotating the body in an asymmetrical (twisted) manner, (e) the joints should be within one third of the maximum movement, (f) provide back support and hips in all seats, and (g) when using muscular force, should be in a position that results in maximum strength. Setiawan (2013) reported that the redesign of the wet blanket workstation reduced worker fatigue by 18.84%.

The findings in this wheelchair product evaluation study were that the respondents' fatigue, especially wheelchair pushers, was significantly increased by 50.20% ($p < 0.05$). This happened as a result of the improvement in working conditions in the form of providing short breaks, regulating work nutrition, and implementing active rest. It is stated so because in providing short breaks it is possible to pay oxygen debt, active rest can change static conditions to dynamic, and work nutrition regulation can overcome glucose deficiency during work activities. It is believed so because several other researchers reported that improving working conditions by implementing ergonomics can reduce fatigue. Research that is comparable to the findings in this study are: (a) Purnomo (2007) reports that workers in the small industry of pottery making in Kasongan, Bantul, experienced a decrease in fatigue by 77.50% ($p < 0.05$) after implementing a work system with the approach total ergonomics; and (b) Widana et al. (2012) reported that the fatigue of vegetable farmers decreased by 13.06% after the implementation of ergonomics in agricultural land processing in Tabanan Bali.

Evaluation of respondents' boredom which is used as a reference in evaluating the development of a product prototype design for the SM-8018 Shima Ergono Wheelchair resulted in a significant decrease of 17.52% ($p < 0.05$). The research is synergized with the research of redesigning wet blanket stations in crumb rubber factories to reduce boredom by 22.32% (Setiawan, 2013).

Evaluation of respondent satisfaction which is used as a reference in evaluating the development of a product prototype design for the SM-8018 Shima Ergono Wheelchair resulted in a significant decrease of 12.85% ($p < 0.05$). Similar but inversely proportional research, namely the redesign of the wet blanket station at the crumb rubber factory increased satisfaction by 31.42% (Setiawan, 2013).

6. Conclusion

Based on the results of data analysis and discussion, it is concluded that the evaluation of the development of the SM-8018 Shima Ergono Wheelchair product prototype design is as follows: The results of the evaluation in the study found that the anthropometric dimensions of the wheelchair were in accordance with the redesign on the seat, back

and head rests, musculoskeletal complaints and fatigue increased, especially for the driving force, significantly 52.05% and 50.20%, decreased boredom and satisfaction by 17.52% and 12.85% ($p < 0.05$). The order of priority of the specification target based on the HoE is; The push handle is made adjustable & ergonomic factor, the holder is made of a material that is not easy to bend when you sit, the backrest and height are not yet according to anthropometry, and need to add a headrest, the stability of the front tire when going through obstacles in the area of incline, descent and slope remains stable

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Biographies

Heri Setiawan is an Associate Professor (Lektor Kepala), and Lecturer of Industrial Engineering Study Program in a Science and Technology Faculty at the Musi Charitas Catholic University, Palembang, South Sumatera, Indonesia. He earned B.S. in Industrial Engineering Department, Industrial Technology Faculty from Atma Jaya University, Yogyakarta, Indonesia. Masters in Industrial Engineering from a 10 November Institute of Technology Surabaya, East Java, Indonesia and PhD in Ergonomic of Work Physiology at Medical Faculty from Udayana University Denpasar-Bali Indonesia. He has published journal and conference papers. Dr Heri Setiawan has completed research projects with BSN, Crumb Rubber Industry, Health-Medical Equipment Industry and Small and Medium Enterprises of potential product in South Sumatera, Indonesia. His research interests include ergonomic, human factor, occupational and health safety, innovative design product, organization and leadership.

Micheline Rinamurti is an Assistant Professor (Lektor), a Vice Rector for Human Resources & Finansial and Lecturer of Management Study Program in a Business and Accounting Faculty at the Musi Charitas Catholic University, Palembang, South Sumatera, Indonesia. She earned B.S. in Management, Faculty of Business and Economic from Gadjah Mada University, Yogyakarta, Indonesia and Masters in Management from Airlangga University Surabaya, East Java, Indonesia. She has published journal and conference papers. Rinamurti has completed research projects with BSN, and Small and Medium Enterprises of potential product in South Sumatera. Her research interests include Human Resources Management, Organizational Behavior, and Social Media Marketing.