Designing chicken feeder aids using Kano-ergonomic function deployment in West Sumatra small and medium sized enterprise

Nilda Tri Putri*, Nabila Humaida and Hilma Raimona Zadry

Department of Industrial Engineering,
Faculty of Engineering,
Universitas Andalas,
Limau Manis, Pauh, Padang City,
West Sumatra 25175, Indonesia
Email: nildatp@eng.unand.ac.id
Email: humaidanabilla@gmail.com
Email: hilma@eng.unand.ac.id
*Corresponding author

Maria Endo Mahata

Department of Animal Science,
Universitas Andalas,
Limau Manis, Pauh, Padang City,
West Sumatra 25175, Indonesia
Email: maria@ansci.unand.ac.id

Elita Amrina

Department of Industrial Engineering,
Faculty of Engineering,
Universitas Andalas,
Limau Manis, Pauh, Padang City,
West Sumatra 25175, Indonesia
Email: elita@eng.unand.ac.id

Abstract: This study aims to design aids for layer chicken feeders in an ergonomic traditional coop using Kano-ergonomic function deployment (EFD). The integration of Kano model and EFD was used to identify design attributes that affect customer satisfaction and to translate customer requirements into technical requirements that are used to determine the priorities for the design of layer chicken feeder aids. The findings of this study are layer chicken feeder aids that are used with pushing movement to overcome musculoskeletal complaints, speed up work time, and reduce feed wastage. This design product is useful to facilitate the feeding of layer chicken as it can reduce musculoskeletal complaints, speed up work time, and reduce feed wastage so that work productivity can increase. In addition, the design of the resulting aids can be used as a reference by chicken layer livestock entrepreneurs to increase the productivity of their companies and especially their workers.

Keywords: livestock feeder aids; ergonomic function deployment; EFD; house of ergonomic; HOE; Kano model; musculoskeletal complaints.

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Biographical notes: Nilda Tri Putri is a Professor in the Department of Industrial Engineering, Faculty of Engineering, Andalas University, Padang, Indonesia. She received her Doctor of Philosophy (PhD) from the Department of Manufacturing and Industrial Engineering, University Technology Malaysia in 2011. She has more than 17 years of teaching/research in the field of quality engineering. Her research interests presently include quality engineering, quality control, product design, and total quality management.

Nabila Humaida is currently a Master student at the School of Business Management, Institut Teknologi Bandung. She obtained her Bachelor's degree in the Department of Industrial Engineering, Faculty of Enginering, Andalas University, Padang in 2020.

Hilma Raimona Zadry is currently working as a Lecturer in the Department of Industrial Engineering, Universitas Andalas, Padang, Indonesia. She obtained her Doctoral degree from the University of Malaya, Malaysia in 2013. Her research interests are ergonomics, work system design, and total quality management.

Maria Endo Mahata is currently working as a Professor in the Department of Nutrition and Feed Technology, Faculty of Animal Science at Universitas Andalas, Padang, Indonesia. She obtained her Doctor's degree in the Departement of Agriculture Science, Universitas Andalas in 2007. She also obtained her Master's degree from affiliation of IPB University and Universitas Andalas at 1987. She has more than 31 years of teaching/research interests in the area of poultry nutrition and feed processing. Her research interests presently are processing of agriculture waste, and utilise the phytochemical material from plan as an alternative feed for improving poultry performance.

Elita Amrina is currently working as an Associate Professor in the Department of Industrial Engineering, Universitas Andalas, Padang, Indonesia. She obtained her Doctoral degree from the Faculty of Mechanical Engineering, Universiti Teknologi Malaysia in 2013. She also obtained her Master's in Industrial and Manufacturing Engineering from the Universiti Teknologi Malaysia in 2010. She has more than 15 years of teaching/research in the field of manufacturing systems. Her current research interests are in sustainable manufacturing, lean manufacturing, and manufacturing performance measurement.

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1 Introduction

Nabila farm is a layer chicken company in Jorong Parumpuang, Nagari Koto Baru Simalanggang, Payakumbuh, West Sumatra, founded in 2000. Nabila Farm produces approximately 56,400 eggs every day with distribution areas covering not only West Sumatra but also Pekanbaru, Jambi, Bengkulu and Jakarta. The wide distribution areas have resulted in Nabila farm having a high demand for eggs, which is around 70,000–80,000 eggs each day, and unfortunately this request cannot be fulfilled by the company.

Feeding activities using *gendongan* or a sling is one of the factors that results in an inefficient process of egg production at the company because it has a negative impact on workers and company owners. Each row of coop has a capacity of 3,800–4,000 chickens, each of which requires 125 gram of feed/day or as a whole only 475 kg/day. However, using *gendongan*, it needs 560 kg of feed/day, with each row of coop wasting about 85 kg/day. This *gendongan* is also used in traditional layer chicken companies outside West Sumatra, such as Blitar, Medan and Cianjur.

Figure 1 Feeding activities using *gendongan* (see online version for colours)

Previous studies found that feeding activities using *gendongan* causes losses to workers. Based on NBM questionnaire, it shows that workers feel a lot of pain in the upper neck, lower neck, left and right shoulders, and right upper arm. These physiological loads are categorised as 'moderate' and are the reasons why improvement in feeding activities is required. Calculation of RWL and lifting index (LI) shows that livestock feeders have risk to human health if lifted manually (Putri et al., 2020). Therefore, it is necessary to design more ergonomic, effective and efficient aids for layer chicken feeders. In this study the design of the feeder aids uses the concept of ergonomic function deployment (EFD) and Kano model. The EFD concept is used to maximise the new relationship between consumer desires and product ergonomics aspects, while Kano model is a categorisation of products or services based on how well the product or service satisfies the customers.

Ergonomics is the study of work harmony in a system consisting of human, machine and work environment (Bridger, 2003). Designing is an activity to create something in accordance with the needs and tastes of consumers, while development is an activity that starts by looking at opportunities and ending with producing, selling and shipping products. In realising the objective of this study, the authors reviewed a number of techniques applied by previous researchers in designing products with the concept of

ergonomics in mind. Some researchers tried to integrate the QFD method with several other methods.

Several studies have applied an ergonomically oriented design. Taifa and Darshark (2015) developed ergonomic classroom furniture by integrating QFD as a tool to understand the overall needs of customers and the Kano model to study customer needs for functions and qualities that match their desire. Wibowo et al. (2017) designed train passenger seats that were previously incompatible with Indonesian people's anthropometry. Suef et al. (2017) used quality function deployment (QFD)-Kano in employing customer complaints and claims and company innovations as the internal data source of customer needs for product development. Then in manufacturing, Vinodh and Chintha (2011) used fuzzy QFD for scientific prioritisation of agile decision domains, agile attributes and agile enablers so as to improve the agility a traditional manufacturing organisation. Kapuria and Rahman (2018) also used fuzzy QFD to identify customer requirements and design the production process and improve the quality of the T-shirts according to the requirements. Mustafa et al. (2009) also used QFD to evaluate the level of ergonomics awareness in manufacturing industries. The integration of Kano model and Kansei engineering was used to get the optimal combination in order to increase customer satisfaction and the quality of mobile phone product designs (Chen and Ming, 2008). Putri et al. (2018) used QFD and TRIZ approach to improve thresher design manufactured by SMEs in West Sumatra. In addition, Jin et al. (2009) used QFD to evaluate the relationship between consumer satisfaction and usability among the physical factors of dishwasher design. Fargnoli et al. (2018) focused their attention on the application of QFD in the design for safety methodology. They focused on the need to identify and analyse the risks related to a working task in an effective manner. Sharma and Sharma (2020) discussed the evaluation of ergonomics in designing working environment for industrial building spaces which includes: illumination, acoustics, thermal, vibration, and utility to improve the efficiency and productivity of work.

Some studies combined several theories, for example AHP, to analyse data and identify customer requirements and Kano-QFD integration to determine the weight of customer needs and technical requirements in developing a modified design (Hridoy and Mohsin, 2020). The SERVQUAL and Kano models were integrated to categorise product and service performance, while QFD was used as a strategy to improve several service attributes by considering the priority of HOQ results (Hartono, 2012). Shahin and Janatyan (2015) proposed a new integrated approach of Taguchi experimental design and Kano model for robust design of service quality. The results of their study help to explain the difference in categorisation of Kano attributes by the new approach in which, customers are directly ask to evaluate the levels of dimensions. Ramos and Silva, et al (2004) used value analysis (VA) to prioritise the increase in the cost of the product and not the subsequent price rise, and QFD to generate clear engineering needs from consumer requirements, minimising the reprojecting cost. Chen (2016) proposed the construction of QFD, combined with the fuzzy decision tree to improve green design of Apple's iPod. Sivasamy et al. (2018a) applied the advanced models namely total quality function deployment (TQFD) to prevent water leakage in a type of pump in a manufacturing company, and Sivasamy et al. (2018b) applied TQFD to overcome low discharge problem in shallow well jet pump as well. They indicated that TQFD is a suitable technique for translating the voice of customers into technical techniques in which employee posse's inadequate expertise to develop House of Quality of QFD technique. Apornak (2017) integrated SERVQUAL model, QFD and Kano in an

educational institution to set the success factors to improve quality in a semi modern college. QFD and SERVQUAL model can also be applied to determine customer's needs in order to enhance banks customers' satisfaction (Gao and Zhou, 2018). Golrizgashti et al. (2020) also proposed an integrated approach, SERVQUAL and fuzzy Kano model to evaluate after-sales services performance for home-appliance industry consumers.

EFD is also applied in product design. Surya et al. (2014) used EFD when re-designing a coconut grated tool. Based on this, in the product development process, determining customers' priority needs is necessary to do. Therefore, in this study the approach of integrating Kano model and EFD was used to design an ergonomic tool based on the customers' priority needs. This study aims to show how Kano model and EFD are useful for designing ergonomic livestock feeder aids.

2 Review of the methods

One method for early customer involvement in product development is the voice of the customer (VoC) [Shen et al., (2001); Melander, 2020). VoC investigates customers' needs and collects a description of these needs using the customers' own words. Needs are divided into basic, articulated and exciting needs (Aguwa et al., 2012; Muramatsu and Kato, 2019). In response to such development, companies have become more innovative and launch new products more frequently (Suef et al., 2017). Basically, Kano model is a useful tool to understand the customer needs and their impact on customer satisfaction (Sanjaykumar et al., 2018). The Kano method was developed by Noriaki Kano in 1984 to categorise product and service attributes based on how well the products/services are able to satisfy the consumers/their needs (Kano et al., 1984). This categorisation is based on the different effects that the fulfilment or non-fulfilment of specific attributes has on customer satisfaction or dissatisfaction (Wang, 2013; Madzik, 2019). The attributes used in the Kano model are divided into six categories, namely (Sauerwein et al., 1996):

1 One-dimensional (O)

   With respect to this requirement, customer satisfaction is proportional to the level of requirements or feature fulfilment. The more the fulfilment, the more the customer is satisfied, and vice versa.

2 Attractive (A)

   This requirement is a product criterion that has a large influence on how the product can satisfy the customer.

3 Must-be (M)

   A must-be requirement is the basic criteria of a product. The fulfilment will only achieve the statement 'does not disappoint'.

4 Indifferent (I)

   Indifferent category is neither a good or bad category by the customer (neutral).

5 Reverse (R)

Reverse category is not a good category and is the opposite of *one dimensional*. The customer is satisfied when the service/product is dysfunctional and is dissatisfied when the service/product is functional.

6 Questionable (Q)

Questionable category indicates that customers are happy when the product is functional and dysfunctional. But they can also be not happy when the product is functional and dysfunctional by choosing a statement of objection.

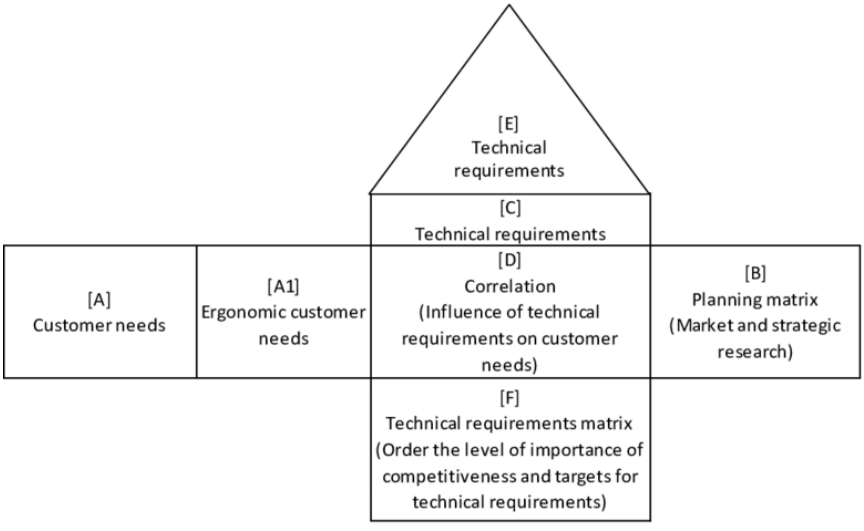
Kano method was often used in previous studies to determine consumer expectations of a product or service. Chen et al. (2009) discussed the direction of the strategy and process of the home industry from the point of view of suppliers and consumers using KANO integrated with TRIZ. Shahin et al. (2017) also integrated TRIZ and the Kano model to improve product quality by evaluating customer needs. Velikova et al. (2016) used the Kano model to consider the 'must-be' or basic factor for wine festivals and estimate the effects of each attribute on the overall satisfaction. Kumar and Routroy (2017) used Kano model and performance VA approaches to capture, plan, and manage supplier's perceptions, expectations, and attractions to a manufacturer, which lead to supplier satisfaction. Mikulic and Prebezac (2011) used the Kano model to review the most commonly used approaches to the classification of quality attribute in managerial practice area. The Kano method can also be applied in the health field as done by Mastrisiswadi and Herianto (2016) in analysing the needs of robot rehabilitation patients, and in the field of service as performed by Shahin and Akasheh (2017) in analysing the need for hospital services. Huang (2018) integrated the Kano model with importance-performance analysis (IPA) to improve the service quality of mobile healthcare as well as to better determine the priority of the quality attributes to be improved. Meanwhile Wu et al. (2020) also combined the Kano model with IPA to identify the factors related to more customer-oriented service quality in the housing service management market. Pandey and Sahu (2020) used the Kano model to improve service quality at cultural and historical heritage sites in India. Oey and Gabriella (2020) integrated Kano model and QFD to improve medium enterprise of export garment manufacturer's marketing and operation management toward their customers. The combination of gap and Kano model helped to identify and quantify the customer attributes.

EFD is a development of QFD, where a new relationship is added to consumer desires and ergonomic aspects of the product. Although the QFD-Kano approach has attracted considerable attention, it still requires a long customer survey. QFD-Kano requires not only data on customer needs but also data on customer satisfaction and dissatisfaction rates. This is why the QFD-Kano approach needs to be improved further to reduce the product development lead time. Utilising company internal data, specifically claims, complaints and company innovation data, may help overcome this weakness, as these data are already available within the organisation (Suef et al., 2017). The house of quality matrix used in QFD was developed into the house of ergonomics (HOE) matrix.

EFD has often been used in previous studies to translate customer needs within the scope of ergonomics in engineering characteristics. Puspitasari and Koekoeh (2016) used EFD as a basis for modification of economic train passenger seats. So did Wibowo et al. (2017) when designing a passenger seat and Fakhira et al. (2017) when designing a gallon washer. Brito et al. (2019) developed the assessment tool, called as ErgoSafeCI, which aimed to improve ergonomics and safety conditions while keeping productive

performance indicators are in focus as well. Kurniawan et al. (2019) developed the design of paper sack packaging conveyors to reduce the risk of musculoskeletal disorders (MSDs) also by using EFD.

Figure 2 House of ergonomic



NBM method, in its application using a worksheet in the form of a body map, is a very simple way, easy to understand, inexpensive and requires a very short-time. Observers can directly ask respondents which parts of the skeletal muscles are affected by pain by pointing directly to each skeletal muscle as listed in the questionnaire worksheet 'nordic body map' (Baru Coelho and Nunes, 2013).

3 Methodology

Procedure of this research was carried out through several stages, namely:

- *First stage:* determining the consumer needs. This was carried out by conducting a preliminary interview to determine the customer needs, conducting customer design and validation, and determining customer needs based on Kano. Analysis of customer needs aims to determine the characteristics of customer needs for livestock feeder aids. This activity began with a direct interview to find out the direction of the questionnaire preparation. The parties directly involved in the design of this tool are the farm owner as a control, workers as users and aids producers. Based on the results of the interview, the seven characteristics of customer needs are grouped into five ergonomic dimensions which are abbreviated as effective, comfortable, safe, healthy and efficient (ENASE). Based on these dimensions, three research questionnaires were then arranged, namely Kano questionnaire, the importance level questionnaire, and the satisfaction level questionnaire, so that each attribute of the questionnaire could represent every customer need. The questionnaire was then validated by the experts so that the selected problems and attributes were matched.

Based on the expert advice, more questions were added, including questions about factors that can strengthen feeder aids-making tools, questions about the tools that the consumers want, and questions related to the comfort level of aids.

- *Second stage:* developing the EFD. This stage included identification of consumer needs based on the results of the questionnaire, determination of the level of importance and satisfaction, preparation of planning matrix, determination of technical responses, and preparation of HOE, which is the compilation of the matrix of the relationship of customer needs with technical responses and the matrix of technical response relationships with consumer needs.
- *Third stage:* developing the guidelines for the use of manual load. This stage was carried out to find out the guidelines for every aspect required based on Minister of Health Regulation No. 48 of 2016 concerning Office Occupational Health and Safety Standards and its alternative controls.
- *Fourth stage:* performing concept selection and testing. This stage was done to bring up and choose alternatives that can be used as a layer chicken feeder aid based on the consumer needs aspect. The method used in the selection of product design was the morphological chart method, which is a combination of various possible solutions in making products based on the obtained technical characteristics. Then an alternative narrowing was done by using the attributes of needs that have been changed into the selection criteria in order to meet consumer needs.
- *Fifth stage:* determining the final specifications. At this stage, the criteria for determining the final specifications of the ergonomic feeder aids were compiled, including the product size and material specifications used in the application of the proposed concept of the product.
- *Sixth stage:* evaluation prototype. Evaluation is carried out as a measure to determine the aids have been able to solve the problems. Some of the factors that are used as benchmarks for evaluating the tools for providing animal feed are *nordic body map* questionnaire, calculation of the workload of the worker's physiology by calculating % CVL and the energy consumption of workers and calculation of the *RWL* for feeding activities using aids.

4 Results and discussion

4.1 First stage: analysis of customer needs

Respondents who filled out and responded to the designed questionnaire that included 13 workers in charge of feeding the chicken at CV Nabila farm and two owners of the chicken farms. The ergonomic dimensions and attributes can be seen in Table 1.

Kano model was used to classify customer attributes or needs. Next step was to calculate the value of each Kano in each attribute of all respondents. With the Blauth formula, it is easier to identify whether the quality offered satisfies the users (workers) or prevents users from dissatisfaction. The following is a recapitulation of the Kano category (Kano et al., 1984).

Table 1 Question attribute

No.	*Criteria*	*Attribute*
1	Effective aspect	
	a The aids are movable	1
	b The aids have a large capacity	2
	c The aids help speed up the feeding process	3
	d The aids are used to assist the process of feeding chickens and collecting eggs	4
2	Comfortable aspect	
	a The aids' height, length and width are adjusted to the size of the user's body and the coop	5
	b The aids do not cause excessive noise	6
	c The aids are lightweight	7
3	Safe aspect	
	a The aids do not cause injuries/complaints	8
	b The aids are strong enough to hold the feed loads	9
	c The aids' design is safe, not pointed at the edges	10
4	Healthy aspect	
	a The aids can reduce complaints on the neck, shoulders, nape and waist	11
	b The aids are not to be carried on the body	12
5	Efficient aspect	
	a The aids' prices range from Rp.500,000–Rp.1,000,000	13
	b The aids are designed as simple as possible to be easy to use	14
	c The aids do not change the state and size of the coop	15
	d The aids are for simultaneous use at the top and bottom of the coop	16
	e The aids are not easily damaged and rusty	17
	f Chance of wasting feed is small	18
	g The aids need less power when used	19

Based on the results of the Kano category recapitulation on each attribute, customer needs that can increase customer satisfaction are those classified as one-dimensional, attractive, and must-be. While the customer needs that are categorised as indifferent were not used because customer satisfaction did not increase regardless of whether these attributes are present or not in a product.

4.2 Second stage: application of the EFD method

The application of EFD is intended to transform the needs of consumers into target specifications which are the development of the technical characteristics of the feeder aids.

Table 2 Recapitulation of Kano categories on each attribute with Blauth's formula method

No.	*Aspect*		*Criteria*	*Kano category*						*Total*	*Grade*
				O	*A*	*M*	*I*	*R*	*Q*		
1	Effective aspect	a	Movable	4	1	6	4	0	0	15	M
		b	Large capacity	5	7	2	1	0	0	15	A
		c	Time saving	10	1	3	1	0	0	15	O
		d	Can be used to assist the process of feeding chickens and collecting eggs.	8	1	4	2	0	0	15	O
2	Comfortable aspect	a	The size suits the size of the user and the coop.	8	5	2	0	0	0	15	O
		b	Not noisy	1	4	1	9	0	0	15	I
		c	Lightweight	7	2	2	4	0	0	15	O
3	Safe aspect	a	Do not cause injuries/complaints	6	2	7	0	0	0	15	M
		b	Strong enough to bear the food loads.	5	0	10	0	0	0	15	M
		c	Not pointed at the edges	3	0	10	2	0	0	15	M
4	Healthy aspect	a	Reduce complaints on the neck, shoulders, nape and waist.	9	3	3	0	0	0	15	O
		b	Not to be carried on the body	7	4	2	2	0	0	15	O
5	Efficient aspect	a	The prices range from Rp.500,000–Rp.1,000,000	7	4	2	2	0	0	15	O
		b	Not easily damaged and rusty	3	8	1	3	0	0	15	A
		c	Not change the state and size of the coop	12	0	3	0	0	0	15	O
		d	Need less power when used	3	2	6	4	0	0	15	M
		e	Simple and easy to use	2	1	4	8	0	0	15	I
		f	Small waste of feed	11	1	3	0	0	0	15	O
		g	For simultaneous use at the top and bottom of the coop	1	2	2	10	0	0	15	I

4.2.1 Identification of customers' needs and expectations

Customer needs used in this study mostly focused on those that can increase customer satisfaction which is the result of processing using the Kano method. Customer needs were classified as one dimensional, attractive, must-be. Customer needs categorised as indifferent and reverse were not used because the existence of this category in the product did not increase customer satisfaction. The customer requirements used in this study can be seen in Table 3.

Table 3 Customer needs

Criteria		*Attribute*	*Value of importance performance*	*Rank*
a	Movable	M	3.33	13
b	Large capacity	A	3.27	15
c	Faster feeding process	O	4.20	5
d	Can be used to assist the process of feeding chickens and collecting eggs.	O	3.73	9
a	The aids' height, length, and width are adjusted to the size of the user's body and the coop.	O	3.73	10
b	Lightweight	O	3.67	12
a	Do not cause injuries/complaints	M	4.40	1
b	Strong enough to bear the food loads	M	4.40	2
c	Safe, not pointed at the edges	M	4.00	6
a	Reduce complaints on the neck, shoulders, nape and waist.	O	3.87	8
b	Not to be carried on the body	O	3.73	11
a	The prices range from Rp.500,000–Rp.1,000,000.	O	4.40	3
b	Not easily damaged and rusty	O	3.33	14
c	Not change the state and size of the coop	A	4.20	4
d	Need less power when used	O	3.93	7
e	Small likelihood of wasted feed	M	4.20	5

4.2.2 Preparation of planning matrix

This stage aims to determine priority values in customer needs and preparation of the HOE. Basis for preparing a *planning matrix* is the level of interest and satisfaction level of the customer. Planning matrix in the design of the livestock feeder aids can be seen in Table 4.

Table 4 Planning matrix

Criteria		*I*	*S*	*Goal*	*R*	*P*	*W*	*N*	*Rank*
a	Movable	3.33	2.60	3.33	1.28	1.50	6.41	0.052	13
b	Large capacity	3.27	3.20	3.27	1.02		5.00	0.041	15
c	Faster feeding process	4.20	3.33	4.20	1.26		7.94	0.065	6
d	Can be used to assist the process of feeding chickens and collecting eggs.	3.73	3.33	3.73	1.12		6.27	0.051	14
a	The aids' height, length, and width are adjusted to the size of the user's body and the coop.	3.73	3.13	3.73	1.19		6.67	0.055	11
b	Lightweight	3.67	2.60	3.67	1.41		7.76	0.063	7
a	Do not cause injuries/complaints	4.40	2.27	4.40	1.94		12.81	0.105	1

Table 4 Planning matrix (continued)

Criteria		*I*	*S*	*Goal*	*R*	*P*	*W*	*N*	*Rank*
b	Strong enough to bear the food loads	4.40	2.53	4.40	1.74	1.50	11.46	0.094	2
c	Safe, not pointed at the edges	4.00	3.40	4.00	1.18		7.06	0.058	10
a	Reduce complaints on the neck, shoulders, nape and waist.	3.87	2.80	3.87	1.38		8.01	0.066	4
b	Not to be carried on the body	3.73	3.13	3.73	1.19		6.67	0.055	12
a	The prices range from Rp.500,000–Rp.1,000,000	4.40	3.60	4.40	1.22		8.07	0.066	5
b	Not easily damaged and rusty	3.33	3.60	3.33	0.93		4.63	0.038	16
c	Not change the state and size of the coop.	4.20	3.53	4.20	1.19		7.49	0.061	9
d	Need less power when used	3.93	2.80	3.93	1.40		8.29	0.068	3
e	Small likelihood of wasted feed	4.20	3.47	4.20	1.21		7.63	0.062	8
Total							*122.17*		

Table 5 Technical characteristics

Attribute no.	*Characteristics*	*Technical characteristics*
1	The aids are movable	The aids are equipped with moving tools
16	The aids need less power when used	
18	Chance of wasting feed is small	
3	The aids help speed up the feeding process	
7	The aids are lightweight	The material uses a slippery plate with a thickness of 1 mm
9	The aids are strong enough to bear the food loads	
13	The aids' prices range from Rp.500,000–Rp.1,000,000	
14	The aids are not easily damaged and rusty	
2	The aids have a large capacity	Each of the feeder can accommodate 30 kg of animal feed
4	The aids are used to assist the process of feeding chickens and collecting eggs	The aids are equipped with a container, with the top adjusting to the shape of the egg paper
5	The aids height, length and width are adjusted to the size of the user's body and the size of the coop	The aids' size is adjusted to the size of the user's body and the coop
15	The aids do not change the state and size of the coop	
8	The aids do not cause injuries/complaints	The aid design pays attention to occupational safety and health standards
10	The aids design is safe, not pointed at the edges	
11	The aids can reduce complaints on the neck, shoulders, nape and waist	
12	The aids are not to be carried on the body	

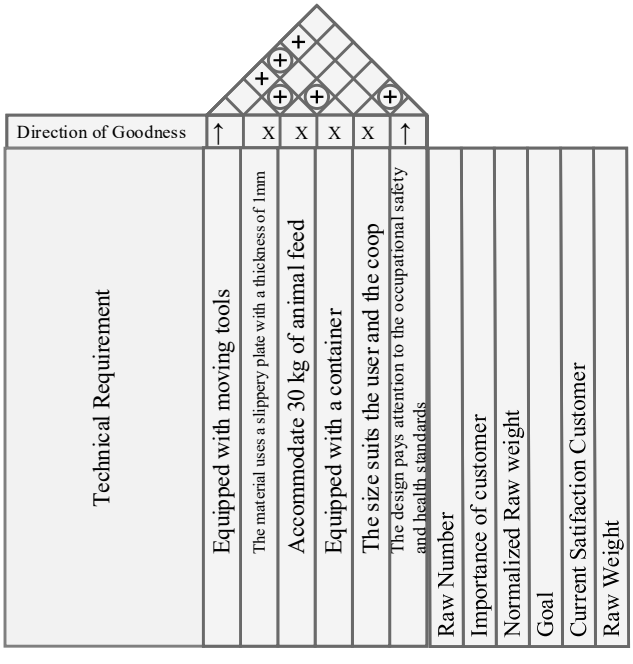
4.2.3 Identification of technical responses

Technical responses contain technical business designs in realising customer needs. Technical characteristics in this study were obtained from interviews conducted with aids producers. This stage was used as a reference in the development alternative models at concept generation stage using a morphological chart.

4.2.4 Determining relationship between technical characteristics

Identification of the relationship between technical characteristics is determined by the correlation between one technical characteristic with another technical characteristic. The level of relationship between the customer and the technical requirements (strong, medium, and weak) in the middle of the matrix are also determined (Cohen, 1995). This stage is very important because the customer's requirements are implemented into the process as technical requirements given its importance for customers. If the value indicates a strong relationship, then the presented technical characteristics must have a major influence because one of the technical characteristics is not applied.

Figure 3 Relationship between technical characteristics



4.2.5 Developing the relationship between customer needs and technical characteristics

In the EFD method, the HOE matrix is used, which is a matrix that is easy to do, measurable and global, which systematically describes the approach taken to design quality products and identify technical characteristics that are appropriate to meet consumer needs. There are three symbols which can briefly be interpreted as a weak,

medium and strong relationship. Without the symbols, there is no relationship between technical characteristics and consumer needs (Cohen, 1995). The relationship between technical characteristics and consumer needs can be seen in Figure 4.

Figure 4 Relationship between technical characteristics and consumer needs

Customer Requirement	Equipped with moving tools	The material uses a slippery plate with a thickness of 1mm	Accommodate 30 kg of animal feed	Equipped with a container	The size suits the user and the coop	The design pays attention to the occupational safety and health standards	Raw Number	Importance of customer	Normalized Raw weight	Goal	Current Satifaction Customer	Raw Weight
Direction of Goodness												
1 The aids are movable	(9)						1	3.3	0.034	3.00	2.69	1.15
2 The aids have a large capacity		(9)	(9)	△1			2	3.27	0.049	4.00	3.20	1.25
3 Faster feeding process	(3)						3	4.2	0.074	5.00	3.33	1.50
4 The aids can be used to collect eggs				(9)			4	3.73	0.074	5.00	3.33	1.50
5 The aids' size suits the size of the user's body					(9)	(3)	5	3.73	0.05	4.00	3.13	1.28
6 The aids are lightweight		(3)				△1	6	3.67	0.06	4.00	2.60	1.54
7 Do not cause injuries						(9)	7	4.40	0.069	4.00	2.27	1.76
8 Strong enough to bear the food loads		(9)					8	4.40	0.062	4.00	2.53	1.58
9 The aids' design is safe						(9)	9	4.00	0.072	5.00	3.40	1.47
10 The prices range from Rp500,000-Rp1,000,000		△1					10	3.87	0.074	5.00	3.33	1.50
11 Reduce physical complaint						(9)	11	3.73	0.05	4.00	3.33	1.28
12 The aids are not to be carried on the body				(9)		(9)	12	4.40	0.068	5.00	3.60	1.39
13 Not easily damaged and rusty		(9)					13	3.33	0.068	5.00	3.60	1.39
14 Do not change the state and size of the coop					(9)		14	4.20	0.069	5.00	3.53	1.42
15 Need less power	(3)						15	3.93	0.056	4.00	2.80	1.43
16 Small chance of feed wastage				(9)			16	4.20	0.071	5.00	3.47	1.44
Contribution	0.87	1.81	0.37	1.56	1.10	2.77						
Priority	5	2	6	3	4	1						

4.2.6 Target specification

The target specification is the result of the development of technical characteristics obtained from the identification of consumer needs. The target specification was determined according to the anthropometric data of the workers and the aids used. The target specification achieved in this study can be seen in Table 6.

Table 6 Target specifications

Technical characteristics	*Target specifications*
The aids are equipped with moving tools	The moving tools come in the form of wheels
The material uses a slippery plate with a thickness of 1 mm	Material can withstand a minimum load of 30 kg
One aid can accommodate 30 kg of chicken feed	The aids are equipped with a container
The aids are equipped with a container, with the top adjusting to the shape of the egg paper	The top of the container is rectangular
The aids' size is adjusted to the size of the user and the coop	The aids do not change the shape and size of the coop
The aids' design pays attention to the occupational safety and health standards	The value of the results of the NBM questionnaire will decrease compared to previous studies.
	The aids meet the occupational safety and health standards, especially item 13 (workforce harmony, equipment, methods and work processes), item 14 (securing and expediting transportation), and item 16 (securing and facilitating loading and unloading).

Target specification was obtained from the results of the researchers' interviews with the planned feeder manufacturers. This stage was used as a reference in the development of alternative models of tools at the concept generation stage using a morphological chart.

The following are the technical characteristics that will be turned into the target specifications after the question and answer's session:

1 Capacity of the feed container.

The capacity of the feed container is based on the feed needs of each chicken. Each chicken needs 110 grams of feed per day, so that the total feed requirement for one layer of coop with a capacity of 250 chickens is ± 27.5 kg/day. The capacity of the container is estimated to be ± 15 kg for 1 layer of coop.

2 The feeder design is adjusted to the operator's body size and the coop size.

The feeder will be designed according to the anthropometric data of the workers as well as the size of the coop so that it can provide an ergonomic impact. This design also will not change the shape, position and size of the existing coop.

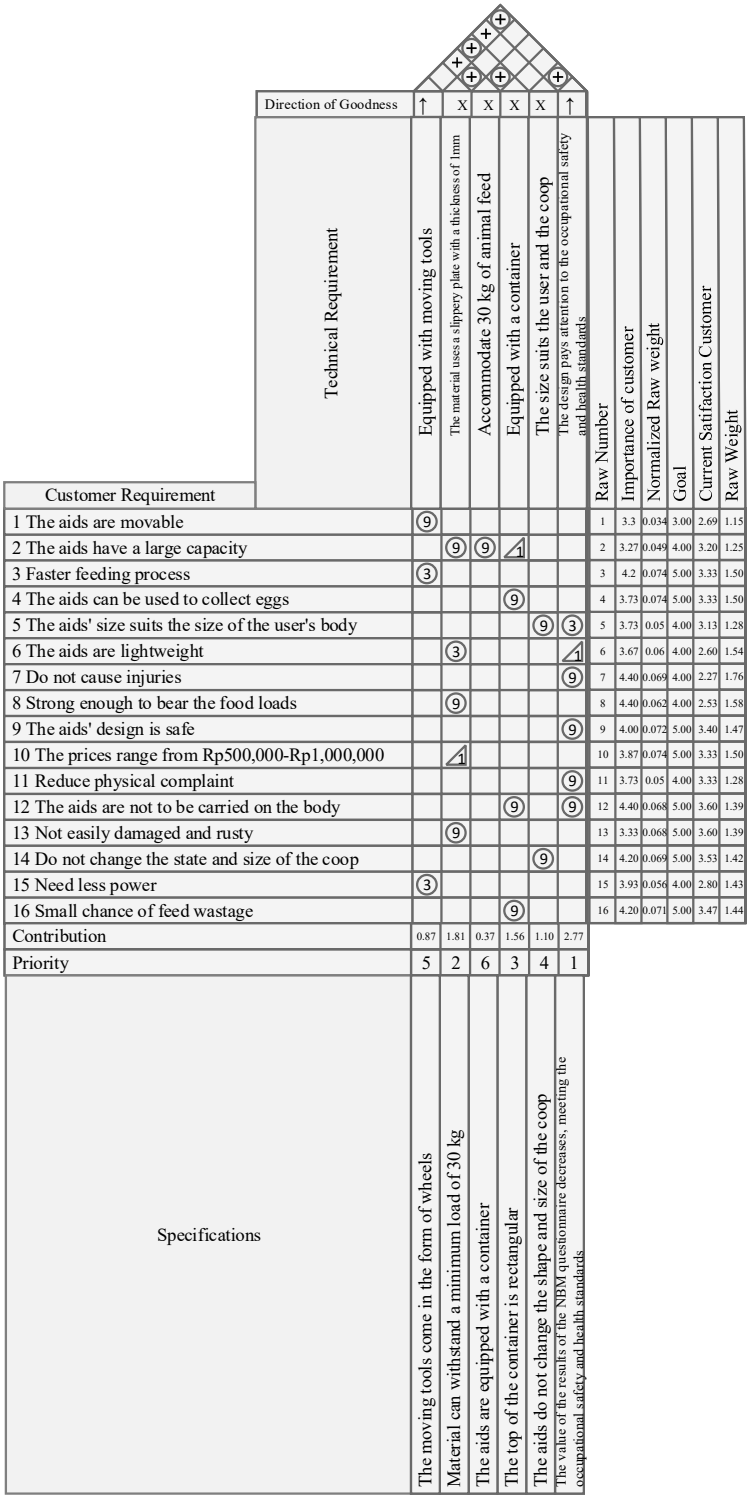
3 The container is made of a plate material with a diameter of 1 mm.

The selection of the container material was done so that animal feed is easily dropped and not stuck because the plate material has slippery characteristics. In addition, the selected plate material also has good resistance to loads so that it can be used for a long period of time.

4 The design of the aids is in accordance with the occupational health and safety standards.

The design of the aids was adjusted to the occupational health and safety standards to ensure that users are free from the risk of accidents/injuries when using them. The fulfilment of the occupational health and safety standards is in accordance with Law No. 1 of 1970 concerning work safety.

Figure 5 House of ergonomic



Based on these results a HOE can be arranged based on the relationship between technical characteristics and the relationship between technical characteristics, customer needs and target specifications.

Table 7 Guidelines for using manual load requirements and its alternative treatments (see online version for colours)

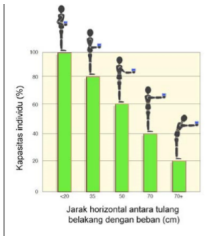
No.	*Aspect*	*The state of the feeding process*	*Treatment based on ministry of health's advice*	*Alternative treatment of manual load based on Permenkes*
			Load characteristics factors	
1a	Is the weight or object more than 3 kg for women and more than 5 kg for men?	Yes, the load carried > 5 kg, or 18–20 kg	 Gambar kapasitas individu saat mengangkat beban atau benda di berbagai jarak horizontal (diadaptasi dari HSE UK)	Based on the picture, if the load ranges between 18–20 kg then the load must lie in one of these two positions: calf height with a distance not exceeding the elbow length, or shoulder height with distance not exceeding the elbow length.
		Has a risk of injury to the spine		Use lifting equipment Reduce the weight of the load or object to be handled Adjust the position and distance of the load or object to the body according to the weight of the load
1b	Is the load or object far from the spine? (no more than 30 cm from the spine)	Yes, the load is more than 30 cm from the spine		Place the weight or object as close to the spine as possible (horizontal distance should be no more than 30 cm from the spine)
		Has a risk of injury to the spine		If this is not possible, set the distance and weight of the load or object in accordance with the provisions in number (1) (a)
1c	Is the size of the load or the object so large that it is difficult to handle? (load dimensions exceed 70 cm)			

Table 7 Guidelines for using manual load requirements and its alternative treatments (continued) (see online version for colours)

No.	*Aspect*	*The state of the feeding process*	*Treatment based on ministry of health's advice*	*Alternative treatment of manual load based on Permenkes*
1d	Is the load or object difficult to handle?	Yes	If the load is difficult to handle, for example because of its large size, round shape, texture being too smooth, wet or oily surface, then handling will require tiring and extra strength and may involve changes in posture, increasing the risk of injury.	Give extra handles, grips, or other features designed to make it easier to lift the object Place the load or object in a containers that is easier to handle
1e	Is the load or object unstable or contains material that is easily moved? (e.g., liquid or powder)	Yes	If the load is unstable, for example because it does not have a rigid shape or contains material that can move easily (such as liquid or powder), then it can cause sudden changes in posture to prevent the material from moving or keep the body stable. As a result the risk of injury will increase.	The packaging must be designed in such a way so that the material (such as liquid or powder) does not suddenly shift during handled Use other tools to maintain the stability of the load or object during handling Fill the container with material (such as liquid or powder) as tightly as possible so that the material does not shift easily.
1f	Does the load or object have sharp, hot or cold parts?			
	Occupational factors (posture, frequency, and duration)			
2a	Does the manual load handling activity involve non-neutral spinal posture (i.e. the ears, shoulders and pelvis are not located on one straight line), including bending and twisting the body?	Yes, feeding activities cause the worker's posture to bend	Pressure on the lower back increases significantly if the spine is bent and twisted, and is exacerbated when lifting loads or objects.	Place the load or object as high as the elbow and as close as possible to the body to avoid non-neutral posture If it is not possible, then lift the load or object with the correct method, i.e. keep your back straight and use the strength of the thigh muscles

Table 7 Guidelines for using manual load requirements and its alternative treatments (continued) (see online version for colours)

No.	*Aspect*	*The state of the feeding process*	*Treatment based on ministry of health's advice*	*Alternative treatment of manual load based on Permenkes*
2b	Are there activities carrying loads or objects over long distances?	Yes, livestock feeding is done by travelling 400 metres twice a day	In general, if a load or object is carried for long distances (about more than 10 metres), then the physical pressure will prolong, causing fatigue and increase the risk of injury.	Use mechanical aids to handle the load Reduce distance and take into account time by rearranging the layout of the workplace.
2c	Is there excessive pushing or pulling activity?	Yes, pushing or pulling activities are sometimes carried out during the feeding process	Limitation of weight or object being pushed, based on the assumption that pushing or pulling activities carried out by hand, loads or objects located at a height between the waist and shoulders, and pushing or pulling activities do not occur at a distance of more than 20 metres, are as follows.	Use aids Use the wheel under the load or object to be pushed or pulled. Consider the distance and condition of the route, whether it is obstacle-free, or with climbs and descent.
2d	Are the activities of manual load handling carried out repeatedly?	Yes, the feed pouring process occurs more than 12 times per minute		Reduces the frequency of lifting activity Minimise unnecessary and hasty movements
2e	Are manual load handling activities carried out statically?	Yes, because the process of feed pouring is done continuously using hand muscles	Static posture occurs when the same muscle is used continuously (for example in weight-bearing activities) or when one has to work with the same posture. If this happens, then excessive pressure will rest on certain body parts or muscles.	Arrange the work in such a way so that variations in posture are possible Take a rest or stretch periodically
2f	Is there adequate rest or recovery time?			

4.3 Third stage: guidelines for using manual load requirements

This guideline explains every aspect required by Permenkes (Minister of Health Regulation) Number 48 of 2016 concerning Office Occupational Safety and Health Standards and its alternative treatments, with the aim of reducing the risk of injury to an acceptable level. This guideline is used as a reference in designing the livestock feeder aids. In accordance with Permenkes No. 48 of 2016, factors that can cause injury will be controlled based on the advice of the Minister of Health. Guidelines for using manual load requirements and the alternative treatments can be seen in Table 7.

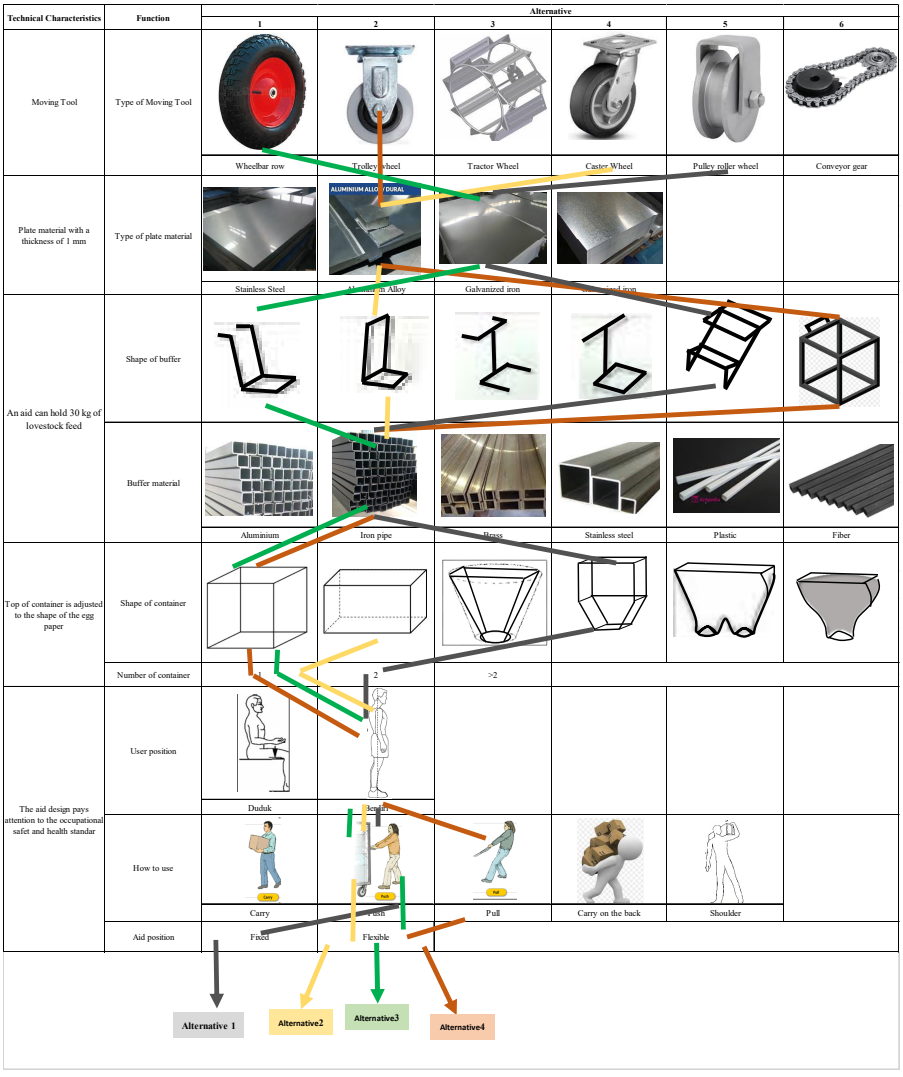
4.4 Fourth stage: concept selection and testing

The following are the overall steps in the concept selection and testing:

4.4.1 Concept generation of livestock feeder aids

One method that can be used in selecting product design is the morphological chart. Morphological charts are used to develop products by taking selected alternatives such as dimensions or advantages of competing products. Morphological chart is a combination of various solutions in making products. The combination design for each function is determined by connecting all functions using a line in order to get some design concepts that later become a reference for determining the final design of the livestock feeder.

Figure 6 Morphological chart (see online version for colours)



Basis for the selection of alternatives for livestock feeder aids:

1 Type of moving tools

Table 8 Type of moving tools

Tools	*Reason*
Wheelbarrow	As a conveyor as well as a container.
Trolley wheel	As a conveyor
Tractor wheel	Perfect conveyor to use on uneven ground.
Pulley roller wheel	Selected as an alternative aid because of its sliding door-like shape.
Conveyor gear	Commonly used as a means of transporting goods.

2 Type of material plate

Table 9 Type of material plate

Tools	*Reason*
Stainless steel	Easy to clean and is a very dense type of metal so it is not easily cracked or dented
Aluminium alloy	Lightweight yet strong because it contains a mixture of magnesium. It is inexpensive and does not cause reactions to objects.
Eser iron	Iron plate is strong, has a durable resistance to corrosion, and is easy to shape.
Galvanised iron	Plate material is slippery as it is coated with zinc on the outside

The combination design for each function was determined by connecting all functions using a line in order to get some design concepts that later become a reference for determining the final design of the livestock feeder.

a Alternative 1

The concept of the tool design can be seen in Table 10.

Alternative 1 of the feeder aid design can be seen in Figure 7.

Figure 7 Alternative 1 of layer chicken feeder aid (see online version for colours)

b Alternative 2

The concept of the tool design can be seen in Table 11.

Table 10 Concept 1 (see online version for colours)

Design	*Type moving tool*	*Type of plate material*	*Shape of buffer*	*Buffer material*	*Shape of container*	*Number of containers*	*User position*	*How to use*	*Tool position*
1	Wheel arrow	Stainless steel	Shape 1	Aluminium	Shape 1	1	Sitting	Carry	Fixed
2	Trolley wheel	Aluminium alloy	Shape 2	Iron pipe	Shape2	2	Standing	Push	Flexible
3	Caster wheel	Eser iron	Shape 3	Brass	Shape 3	> 2		Pull	
4	Pulley roller wheel	Galvanised iron	Shape 4	Stainless steel	Shape 4			Carry on the back	
5	Conveyor gear		Shape 5	Plastic	Shape 5			Shoulder	
6			Shape 6	Fibre	Shape 6				

Table 11 Concept 2 (see online version for colours)

Design	*Type of moving tool*	*Type of plate material*	*Shape of buffer*	*Buffer material*	*Shape of container*	*Number of containers*	*User position*	*How to use*	*Tool position*
1	Wheel barrow	Stainless steel	Shape 1	Aluminium	Shape 1	1	Sitting	Carry	Fixed
2	Trolley wheel	Aluminium alloy	Shape 2	Iron pipe	Shape 2	2	Standing	Push	Flexible
3	Caster wheel	Eser iron	Shape 3	Brass	Shape 3	> 2		Pull	
4	Pulley roller wheel	Galvanised iron	Shape 4	Stainless steel	Shape 4			Carry on the back	
5	Conveyor gear		Shape 5	Plastic	Shape 5			Shoulder	
6			Shape 6	Fibre	Shape 6				

Table 12 Concept 3 (see online version for colours)

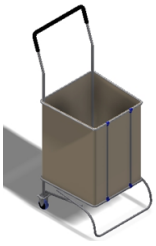
Design	*Type of moving tool*	*Type of plate material*	*Shape of buffer*	*Buffer material*	*Shape of container*	*Number of containers*	*User position*	*How to use*	*Tool Position*
1	Wheel barrow	Stainless steel	Shape 1	Aluminium	Shape 1	1	Sitting	Carry	Fixed
2	Trolley wheel	Aluminium alloy	Shape 2	Iron pipe	Shape 2	2	Standing	Push	Flexible
3	Caster wheel	Eser iron	Shape 3	Brass	Shape 3	> 2		Pull	
4	Pulley roller wheel	Galvanised iron	Shape 4	Stainless steel	Shape 4			Carry on the back	
5	Conveyor gear		Shape 5	Plastic	Shape 5			Shoulder	
6			Shape 6	Fibre	Shape 6				

Table 13 Concept 4 (see online version for colours)

Design	*Type of moving tool*	*Type of plate material*	*Shape of buffer*	*Buffer material*	*Shape of container*	*Number of containers*	*User position*	*How to use*	*Tool position*
1	Wheel barrow	Stainless steel	Shape 1	Aluminium	Shape 1	1	Sitting	Carry	Fixed
2	Trolley wheel	Aluminium alloy	Shape 2	Iron pipe	Shape 2	2	Standing	Push	Flexible
3	Caster wheel	Eser iron	Shape 3	Brass	Shape 3	> 2		Pull	
4	Pulley roller wheel	Galvanised iron	Shape 4	Stainless steel	Shape 4			Carry on the back	
5	Conveyor gear		Shape 5	Plastic	Shape 5			Shoulder	
6			Shape 6	Fibre	Shape 6				

Alternative 2 of the feeder aid design can be seen in Figure 8.

Figure 8 Alternative 2 of layer chicken feeder aid (see online version for colours)

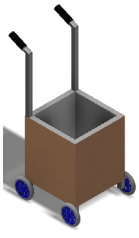


c Alternative 3

The concept of the tool design can be seen in Table 12.

Alternative 3 of the feeder aid design can be seen in Figure 9.

Figure 9 Alternative 3 of layer chicken feeder aid (see online version for colours)

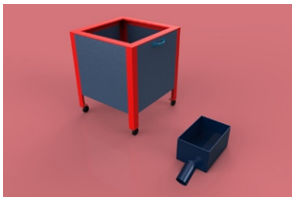


d Alternative 4

The concept of the tool design can be seen in Table 13.

Alternative 4 of the feeder aid design can be seen in Figure 10.

Figure 10 Alternative 4 of layer chicken feeder aid (see online version for colours)



4.4.2 Concept screening of livestock feeder aids

At this stage the process of concept screening to the alternative design of livestock feeder aids was done using a number of needs attributes that had been changed into selection criteria to meet the consumers' needs. Among the selection criteria that serve as references to customer needs are:

a Effective, meaning the goals or targets that have been determined can be achieved.

b Comfortable, meaning when someone is required to provide a stable level of performance, they feel free from the risk of injury.

c Safe

d Healthy, meaning things that can cause disturbances are kept away.

e Efficient, meaning goals are achieved with low effort, cost and sacrifice.

The results of concept screening of the alternative criteria for livestock feeder aids can be seen in Table 15.

Table 14 Concept screening (see online version for colours)

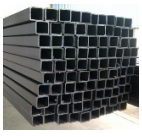
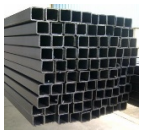
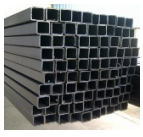
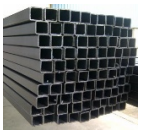
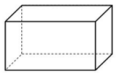
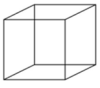
Technical characteristics	*Function*	*Alternative*			
		1	*2*	*3*	*4*
Moving tool	Type of moving tool				
		Pulley roller wheel	Caster wheel	Wheelbarrow	Trolley wheel
	Expert 1	(+)	(–)	(–)	(–)
	Expert 2	(-)	(+)	(–)	(–)
Plate material with a thickness of 1 mm	Type of plate material				
		Eser iron	Aluminium alloy	Eser iron	Aluminium alloy
	Expert 1	(+)	(–)	(+)	(–)
	Expert 2	(–)	(+)	(–)	(+)
An aid can hold 30 kg of livestock feed	Shape of buffer				
	Expert 1	(–)	(+)	(–)	(–)
	Expert 2	(+)	(–)	(–)	(–)
	Buffer material				
		Iron pipe	Iron pipe	Iron pipe	Iron pipe
	Expert 1	(o)	(o)	(o)	(o)
	Expert 2	(o)	(o)	(o)	(o)
Top of container is adjusted to the shape of the egg paper	Shape of container				

Table 14 Concept screening (continued) (see online version for colours)

Technical characteristics	*Function*	*Alternative*			
		1	*2*	*3*	*4*
Top of container is adjusted to the shape of the egg paper	Expert 1	(–)	(+)	(–)	(–)
	Expert 2	(+)	(–)	(–)	(–)
	Number of containers	2	1	1	1
	Expert 1	(+)	(–)	(–)	(–)
	Expert 2	(+)	(–)	(–)	(–)
The aid design pays attention to occupational safety and health standards.	User's position				
		Standing	Standing	Standing	Standing
	Expert 1	(o)	(o)	(o)	(o)
	Expert 2	(o)	(o)	(o)	(o)
	How to use				
		Push	Push	Push	Pull
	Expert 1	(+)	(+)	(+)	(v)
	Expert 2	(+)	(+)	(+)	(–)
	Tool position	Fixed	Flexible	Flexible	Flexible
	Expert 1	(–)	(+)	(+)	(+)
	Expert 2	(–)	(+)	(+)	(+)
Total +		8	8	5	3
Total 0		4	4	4	4
Total–		6	6	9	11
Final score		2	2	–3	–8
Rank		*1*	*1*	*2*	*3*
Continue?		*Yes*	*Yes*	*No*	*No*

4.4.3 Concept scoring of livestock feeder aids

This stage aims to determine the product design that will be selected as the final concept in the process of evaluating several design alternatives. The following is the concept scoring of livestock feeder aids selection.

Table 15 Concept scoring

Attribute no.	*Design criteria*	*N*	*Alternative*			
			2		*3*	
	Moving tool	0.052	Control roller wheel		Caster wheel	
1	*Expert 1*		3	0.16	2	0.10
	Expert 2		2	0.10	4	0.21
	Type of plate material	0.094	Eser iron		Aluminium alloy	
2	*Expert 1*		5	0.47	2	0.19
	Expert 2		4	0.38	3	0.28
	Shape of buffer	0.051	Shape 5		Shape 2	
3	*Expert 1*		5	0.26	2	0.10
	Expert 2		4	0.20	3	0.15
	Shape of container	0.041	Shape 5		Shape 2	
4	Expert 1		5	0.26	2	0.10
	Expert 2		4	0.20	3	0.15
	Number of containers	0.051	2.00		1.00	
5	*Expert 1*		3	0.15	4	0.20
	Expert 2		3	0.15	3	0.15
	Tool position	0.038	Fixed		Flexible	
6	*Expert 1*		2	0.10	5	0.26
	Expert 2		2	0.10	2	0.10
	Expert 1 score		1.24		0.96	
	Expert 2 score		1.20		1.21	
	Total		2.44		2.17	
	Rank		*1*		*2*	

Based on the results of the concept scoring of several design alternatives as presented in Table 15, it is known that the concept that will be continued to the evaluation stage is concept one.

4.5 Fifth stage: final specifications

The product manufacturing process requires criteria that involve product size and material specifications used in the application of the proposed product concept to determine the final specifications of ergonomic tools. The final specifications of the aids can be seen in Table 16. Meanwhile, the dimension for feeder aids refers to guidelines for using manual load requirements and its alternative treatments as shown in Table 17.

Table 16 Final specifications of feeder aids

No.	*Technical importance*	*Target specifications*	*Target value*	*Unit*
1	Each aid is equipped with moving tools	The moving tools come in the form of wheels	Yes	-
	The material uses a slippery plate with a thickness of 1 mm.			
2	Each aid can hold 30 kg of livestock feed.	The material can withstand a minimum load of 30 kg	30	kg
	Aids are equipped with a container, with the top adjusted to the shape of the egg paper.			
3	The aid size is adjusted to the size of the user's body and the coop.	The aid is equipped with a container	Yes	-
4	Each AID is equipped with moving tools.	The top of the container has a square/rectangular shape	31.5 × 31.5	cm
	The material uses a slippery plate with a thickness of 1 mm.			
5	Each aid can hold 30 kg of livestock feed.	No need to change the shape and size of coops	Yes	-
	Aids are equipped with a container, with the top adjusted to the shape of the egg paper.			
6	The aid size is adjusted to the size of the user's body and the coop.	The value of the results of the NBM questionnaire will decrease compared to previous studies	2 (less painful)	score
		The aids meet the occupational safety and health standards, especially item 13, 14, and 16	Yes	-

Table 17 Aids dimensions

No.	*Part*	*Dimension (cm)*	*Information*
1	Lengthy	49.5	This size based on anthropometric dimension approach to the front hand span of the worker with the 5th percentile. The selection of hand span anthropometric dimensions is intended to make it easier for workers to reach the tool. The 5th percentile was chosen so that workers with short reach could still adjust it.
2	Height	130	*Adjustment with cage size:* height of the feed funnel is determined based on the height of the cage (50 cm), the distance between the feed and the egg storage (5 cm), the distance of cage from the bottom to the ground (60 cm), and the distance between wheels and rail (14 cm) so the total is 129 cm.

Table 17 Aids dimensions (continued)

No.	*Part*	*Dimension (cm)*	*Information*
2	Height	130	*Adjustment with anthropometric:* based on Permenkes (Minister of Health Regulation) Number 48 of 2016 concerning Office Occupational Safety and Health Standards at Table 7 give recommendation that the height of the aids parallel with the shoulder of the workers with 5th percentile (130.2 cm)
3	Distance between the upper and lower part of the feed container frame	8	The size based on the distance between upper feed bin and the lower cage (5 cm) to reduce friction between aids and cage
4	Height feed funnel	7.5	The size of the feed funnel is obtained from the approximate height of the feed container (10 cm).

4.6 Sixth stage: evaluation prototype

The following is a comparison of the aspects of ergonomics before and after designing the tools.

Table 18 Comparison of convenience before and after designing tool

No.	*Indicator*		*Before designing tools*	*After designing tools*
1	NBM questionnaire	Upper neck	3	1
		Neck	3	2
		Left shoulder	3	1
		Right shoulder	3	2
		Left upper arm	2	1
		Back	2	1
		Right upper arm	2	2
		Waist	3	3
		Hips	2	1
		Butt	2	1
		Left elbow	1	1
		Elbow right	1	1
		Forearm left	1	1
		Forearm right	2	2
		Left wrist	2	0
		Wrists right	3	1
		Left hand	2	1
		Right hand	1	1
		Thigh left	1	0
		Thigh right	1	1

Table 18 Comparison of convenience before and after designing tool (continued)

No.		*Indicator*	*Before designing tools*	*After designing tools*
1	NBM questionnaire	Left knee	1	1
		Right knee	1	0
		Left knee	3	1
		Right calf	3	1
		Left ankle	1	0
		Right ankle	1	1
		Left foot	1	0
		Right foot	1	0
2	Workload physiological	% cvl	60.7% (short work)	31.1% (required repair)
		Energy expenditure	5.13 kcal/minute (medium light)	2.13 kcal/minute (very light)
3	Feeding time		55–65 minutes/cage	25–30 minutes/cage
4	Feeding need		560 kg/day/cage	480 kg/day/cage

5 Conclusions

Combination of the EFD approach and the Kano model produces a conceptual design of layer chicken feeder aids that suits customer preferences. The significant difference between the newly designed aids and 'gendongan' that the aids are designed semi-automatically using wheels to facilitate mobilisation and move the pedestal away from the shoulders of the worker. The aids are also designed so that their use involves pushing movements to minimise complaints on the shoulders and waist of the user. The aids capacity is also designed in accordance with the feed needs of each coop layer so as to meet the criteria of consumer needs. In the future the aids that have been designed in this study will be applied at chicken farms in Payakumbuh, West Sumatra, Indonesia for further improvements.

Based on the design of aids that has been tested and evaluated on the design components, it shows that aids can reduce complaints from both the workers and the company it show on musculoskeletal complaints, speed up feeding time, and reduce wasted feed. This can be seen from the fact that there is no longer any wasted feed and the feeding process has accelerated 2x faster than before so that the aids can make production activities in small medium enterprise chicken farms more effective and efficient.

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