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Editorial Office:

Editor- in-Chief,
Applied Bio-Systems Technology,
Faculty of Agriculture & Plantation Management,
Wayamba University of Sri Lanka,
Makandura, Gonawila, 60170,
Sri Lanka.

Tel : +94-31 229 7075
E-mail : abse@wyb.ac.lk
Fax : +94-31 229 9248

Editorial Assistant: *Ms. L.H. Nadeera De Silva*

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Research Article **Open Access**

Effect of Particle Size of Oat (*Avena sativa*) Flakes on Physicochemical and Sensory Properties of Oat Incorporated Drinking Yoghurt

Hansani De Silva[1], Geethi Pamunuwa[1]* and Amani Wijesinghe[2]

Abstract

Background: Consumption of oats (*Avena sativa*) has increased steeply over the last few years due to the multiple health benefits shown by its constituents, including dietary fibre. Accordingly, numerous functional foods have been formulated incorporating oats. The aim of this study was to determine the optimum particle size of oat flakes for the development of oat incorporated drinking yoghurt.

Methods: Drinking yoghurt was formulated incorporating oat flakes of particle sizes 850-425 µm, 425-180 µm and <180 µm. Physicochemical parameters of the formulated drinking yoghurts, including pH, Titratable Acidity (TA), Total Soluble Solids (TSS), degree of syneresis and firmness were determined for 21 days. The sample that showed the best sensory attributes and physicochemical properties was analysed for proximate composition and microbial safety.

Results: The sensory attributes of the drinking yoghurts with oat flakes of three different particle sizes were not significantly different ($P>0.05$). The particle size of oat flakes affected the physicochemical properties of drinking yoghurts. In fact, the yoghurt with oat flakes of the smallest size showed the highest titratable acidity, TSS and firmness in the drinking yoghurt ($P\leq0.05$). The variation of the physicochemical properties of the yoghurts with time followed a similar pattern. In fact, the pH decreased, TA increased, while TSS decreased with time ($P\leq0.05$). The selected drinking yoghurt, which was prepared incorporating oat flakes of size range 850-425 µm and 300 ppm of potassium sorbate, showed a shelf life of 14 days at 4 °C. It exhibited similar sensory attributes other than taste to a popular drinking yoghurt from the market.

Conclusions: Drinking yoghurt incorporated with oat flakes of 850-425 µm size range showed a better taste and nutritional profile, than regular yoghurt.

Keywords: Drinking Yoghurt, Oat Flakes, Particle Size, Physicochemical Properties, Sensory Properties

[1]Department of Horticulture and Landscape Gardening, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Gonawila, Makandura, Sri Lanka
[2]Department of Biosystems Engineering, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Gonawila, Makandura, Sri Lanka

* Correspondence: geethip@wyb.ac.lk
https://orcid.org/0000-0002-1156-5088

INTRODUCTION

The formulation of novel foods and beverages with increased nutrient content has shown an upward trend worldwide allowing the consumers to have easy access to a balanced diet [1]. This approach is much favourable since unbalanced diets could lead to numerous non-communicable diseases such as diabetes, hypercholesterolemia and cancer. Unfortunately, the incidence of non-communicable diseases has shown a steep increase in numerous countries in the last two decades, highlighting the importance of formulating healthy foods and beverages [2].

The popularity of fermented dairy products is increasing among people around the globe continuously mostly as a result of extensive product diversification. Yoghurt drink, which is a ready-to-drink beverage produced from yoghurt of low viscosity, is an exceedingly successful fermented beverage developed quite recently. Regular consumption of yoghurt could lead to numerous health benefits including enhanced lactose tolerance, hypocholesterolemic effects, and anticancer properties. Further, it is also capable of stimulating the immune system and controlling gastrointestinal infections [3]. Drinking yoghurt, which shows numerous health benefits and of high popularity, is indeed an excellent beverage for fortification with nutrients. Like many non-fermented beverages fortified with nutrients [4-5], drinking yoghurt also could be fortified with numerous nutrients, including vitamins [6], minerals [7-8], and insoluble dietary fibre derived from different cereals such as oats [9] to provide further health benefits.

Oat (*Avena sativa*) is a cereal, rich in nutrients. Dietary fibre including β-glucan, high amounts of tocopherols and polyunsaturated fatty acids are the main nutrients responsible for the functional attributes of oats [10]. Health benefits of oats are many. Regular consumption of oats can reduce the blood low-density lipoprotein (LDL) cholesterol level, decrease the risk of cardio vascular diseases, and reduce the blood glucose level thereby declining the risk of type-2 diabetes mellitus. Further, it can lessen the risk of gastrointestinal disorders and cancer. Dietary fiber is responsible for most of the health benefits of oats [11]. Total dietary fibre intake by an adult should be approximately 28-36 g per day and it is highly essential for maintaining the health of the digestive system [2].

However, the daily dietary fibre intake by people of numerous countries is lower than the recommended level, highlighting the need for fibre fortified food products [2, 12]. Catering to the need of fiber fortification, Malki *et al.* [13] has formulated a set yoghurt incorporating oat flakes. Accordingly, incorporation of oats or its fractions into drinking yoghurt will be an appealing way of developing a functional food, which supplies the daily dietary fibre need.

In addition to functioning as an excellent source of dietary fibre, oat starch has been reported to function as a thickening or gelling agent in food formulations [14]. The characteristic large setback viscosity of oat starch explains the formation of thick gels by this thickener [15]. Thus, oat flakes, which are moderately processed oats that show easy gelatinization, may function as thickening agents for yoghurt products. However, sedimentation of the large particles may be problematic. Hence, powdered oat flakes may be a promising thickening agent for drinking yoghurt.

The particle size of oat flakes used in drinking yoghurt preparation may directly cause changes in sensory attributes like mouthfeel, sweetness and texture. This can also influence certain physicochemical properties like pH, titratable acidity, total soluble solids, syneresis and firmness of the final product. With this background, the present study was conducted to investigate the effect of the incorporation of three different particle sizes of oat flakes (850-425

μm, 425-180 μm, <180 μm) on the physicochemical and sensory attributes of drinking yoghurt.

METHODOLOGY

Materials

Oat flakes were purchased from Stassen Exports Pvt. Ltd., Colombo, Sri Lanka. Fresh cow milk of acceptable organoleptic and microbial quality was obtained from a reputed local supplier (Kothmale Holdings PLC, Sri Lanka). Sucrose, milk solids (Nestle Lanka PLC, Sri Lanka), potassium sorbate (INS No. 202) and drinking yoghurt were purchased from a local retail market. The starter culture with *Lactobacillus bulgaricus* and *Streptococcus thermophiles* microorganisms was procured from the Veterinary Research Institute, Gannoruwa, Sri Lanka.

Preparation of Oat Incorporated Drinking Yoghurt

Fresh milk (1000 mL) was pasteurized at 80 °C, while stirring continuously. Sucrose (90 g), milk solids (10 g) and oat flakes of reduced particle size obtained through milling and sieving (5 g) were mixed into the heated milk, which was then homogenized at 90 °C for 15 min. After cooling the sample down to 50 °C, potassium sorbate, which is a permitted preservative according to the Sri Lanka standard SLS 824:1989, was added such that the final concentration was 300 ppm (300 mg/kg) [16].

At 42 °C, the yoghurt starter culture was added (according to the recommendation of the Veterinary Research Institute, Sri Lanka) and the sample was stirred for the complete dissolution of the starter culture. Then, the sample was incubated at 42 °C for 4-5 h until a soft curd was formed and the pH of the sample reach to pH 4.6. The incubated sample was refrigerated overnight at 4 °C, and the curd was broken by swirling 40 times with a handheld stirrer to form a homogeneous product. The sample was refrigerated at 4 °C, until further analysis.

Three different particle sizes of oat flakes were used separately as thickening agents in the preparation of three different types of drinking yoghurts (Table 1).

Table 1: Three Different Sizes of Oat Flakes used in Drinking Yoghurt

Treatment	Size of Oat Flakes (μm)
T1	850-425
T2	425-180
T3	<180

Physicochemical Properties

Physicochemical variations of the three different types of oat incorporated drinking yoghurts (treatments) stored at refrigerated conditions (4 °C) were observed for 21 days. The pH was determined using a digital pH meter (EZODO, Taiwan). Titratable Acidity (TA) was determined by titrating aliquots of yoghurt samples with 0.1 N NaOH using phenolphthalein as the indicator as recommended by Association of Official Analytical Chemists (AOAC) [17]. Total Soluble Solids (TSS) content was obtained by a handheld refractometer (ATAGO N-46, Japan) and expressed as Brix%. The parameters stated above were monitored at 3-day intervals. Syneresis was measured for a period of 21 days at 7-day intervals, along with the Texture (firmness), which was measured using a texture analyser. All the analyses were performed in triplicate [18].

Sensory Evaluation

The sensory evaluation was carried out using thirty (30) untrained panellists. The panellists were asked to access nine parameters: colour, mouthfeel, odour, sweetness, sourness, taste, texture and overall quality, and purchasing intension of the drinking yoghurts, using a 5-point hedonic scale.

A second sensory evaluation was carried out comparing the best treatment from the study with a popular drinking yoghurt from the market (M). Similar to the first sensory analysis, the panellists were

asked to access the aforementioned sensory parameters [19].

Proximate Analysis

Proximate analysis was carried out for the best sample selected based on the physicochemical and sensory analyses. It was compared with the drinking yoghurt from the market (M). The moisture content, ash content, total solid and solids-non-fat content were analysed according to the standard methods recommended by AOAC [17]. The crude fibre content was determined according to Weende method [20]. Total fat content was determined by the Soxhlet extraction method, while the crude protein content was determined by the Kjeldhal method [17]. The total carbohydrate content was determined according to a standard formula [21]. Analyses were performed in triplicate.

Microbiological Analysis

Microbiological analysis was carried out for the best drinking yoghurt (treatment) selected according to the sensory and physicochemical properties. Plate count agar was used for the determination of total viable counts. Analysis was carried out according to SLS 824 [16] for 21 days at 7-day intervals using yoghurt samples refrigerated at 4 °C. Microbial counts were obtained in 24 h.

Statistical Analysis

Data of sensory evaluation were analysed by using the Friedman test, while parametric data were analysed using one-way Analysis of Variance (ANOVA) and two-way ANOVA in OriginPro (version 9) software. Mean comparison was carried out using Fisher LSD method at $p \leq 0.05$ significance level. Data was expressed as Mean ± SD (SD: Standard Deviation).

RESULTS AND DISCUSSION

Physicochemical Analysis

The variation of physicochemical parameters of the three different drinking yoghurts (treatments) with storage time is shown in Figures 1 – 5.

pH

As shown in Figure 1, the pH of all treatments decreased significantly ($P \leq 0.05$) with time until 21 days. This decrease may be due to the excessive sugar fermentation by the lactic acid producing microorganisms [22]. Overall, the pH of treatments T1, T2 and T3 were not significantly different. However, significant differences ($P \leq 0.05$) among the treatments were observed at each time interval. According to Sri Lanka Standard SLS 824: 1989 [16], the pH of drinking yoghurt should be pH 4.5 and the pH of the treatments showed approximately similar values. Maintaining this optimum pH is important, since pH higher than 4.5 may facilitate the growth of pathogenic organisms, while pH lower than 4.5 may increase alcoholic aroma and acidic taste in yoghurt. The decrease of pH and increase of TA have been observed in many other yoghurt preparations [23].

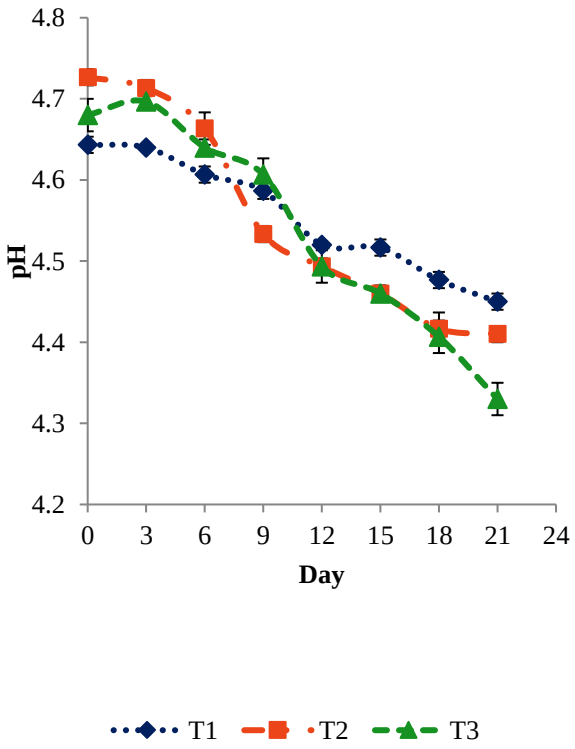

Figure 1: Variation of pH of Oat Incorporated Drinking Yoghurts with Time (Mean ± SD)
Note: T1: Oat flakes of size 850-425 µm incorporated yoghurt, T2: Oat flakes of size 425-180 µm incorporated yoghurt, T3: Oat flaks of size <180 µm incorporated yoghurt

Titratable Acidity (TA)

As shown in Figure 2, TA of all treatments increased significantly ($P \leq 0.05$) with time. The increase in TA with time is due to the fermentation of lactose, producing lactic acid [22]. The TA of T3 was significantly higher than that of T1 and T2, which were not significantly different based on the post-hoc analysis of means (Table 3). The water holding capacity of oat flakes may increase with reducing particle size due to higher release of fibre and starch that bind water. It may lead to lower water activity of T3, than T1 and T2. The higher acidity of T3 may have resulted, mainly, due to its higher water holding capacity than T1 and T2. The lower amount of free water molecules of T3 to dilute the lactic acid formed is reflected by its higher TA, compared to T1 and T2.

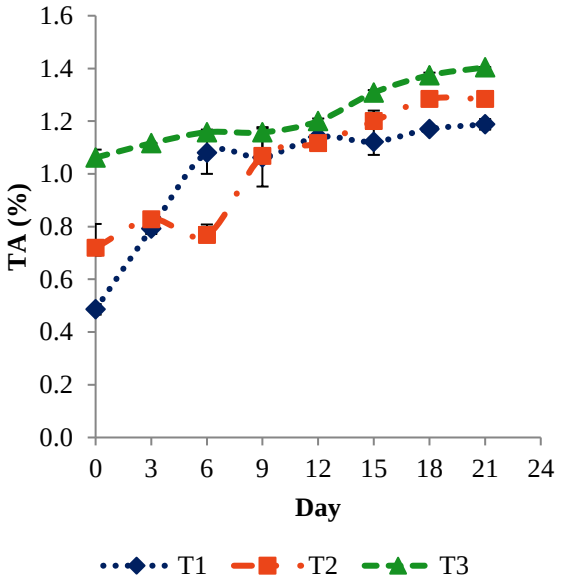

Figure 2: Variation of TA (%) of Oat Incorporated Drinking Yoghurts with Time (Mean ± SD)

Note: TA: Titratable Acidity, T1: Oat flakes of size 850-425 µm incorporated yoghurt, T2: Oat flakes of size 425-180 µm incorporated yoghurt, T3: Oat flaks of size <180 µm incorporated yoghurt

Total Soluble Solids (TSS)

As expected, TSS of all three treatments decreased with time ($P \leq 0.05$) as shown in Figure 3. The main reasons for this decrease are the consumption of sucrose by the microbes as an energy source and conversion of sugars into lactic acid through fermentation [24]. The TSS of the yoghurts increased with decreasing particle size of oat flakes. In fact, TSS of three treatments in the increasing order was: T1<T2<T3, while the mean values were 21.2%, 22.9% and 23.6%, respectively. This variation may be due to the higher degrees of leaching out of soluble material from oat flakes of lower particle size, due to their high surface area [25]. Further, the high degree of intact complexation of amylose to lipids in large oat flakes may have retarded leaching of soluble material, in addition to amylose, to the medium thereby showing lower TSS values [26].

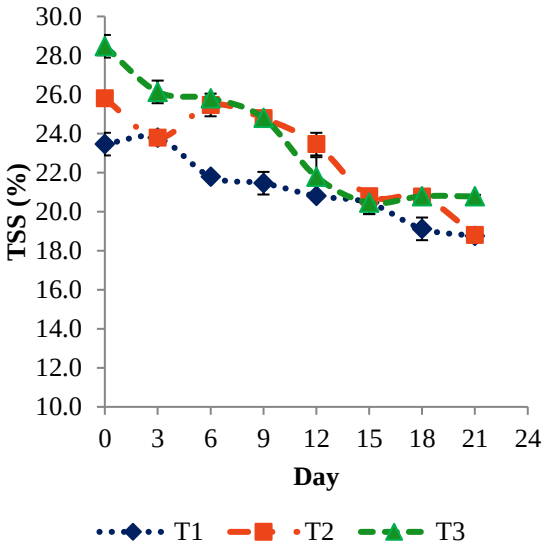

Figure 3: Variation of TSS of Oat Incorporated Drinking Yoghurts with Time (Mean ± SD)

Note: TSS: Total Soluble Solids, T1: Oat flakes of size 850-425 µm incorporated yoghurt, T2: Oat flakes of size 425-180 µm incorporated yoghurt, T3: Oat flaks of size <180 µm incorporated yoghurt

Syneresis and Firmness

Syneresis indicates the amount of whey separation. Overall, the syneresis of the three treatments was not significantly different at $P \leq 0.05$ level (Figure 4). However, the syneresis in the decreasing order was: T1≥T2≥T3, indicating that the syneresis of T1 was greater than that of T3. However, the mean difference between T1 and T3 was 0.41% only. As it was mentioned previously, oats show pronounced swelling and leaching

of soluble glucan during gelatilinization [27]. The T3 treatment, which consisted of the smallest size of oat flakes may have leached out more soluble glucan, amylose and amylopectin than T1, affecting the yoghurt microstructure leading into a higher water holding capacity and lower degree of syneresis [28].

Syneresis increased in all treatments with storage time and this may be due to loosing of casein network in the yoghurt gel [29]. Although many reasons such as those discussed above may explain the low degree of syneresis of T3, the overall results show that syneresis was not significantly different among the three treatments, as mentioned previously. However, the texture (firmness) of the three treatments was significantly different ($P \leq 0.05$). T3 showed a higher firmness than T1 and T2, which showed similar firmness levels (Figure 5). It may be due to the distinct effects of oat flakes of different particle sizes on the microstructure of yoghurt and varied water holding capacities of the three treatments. Favourably, the firmness of all treatments showed no significant variations with storage time ($P > 0.05$).

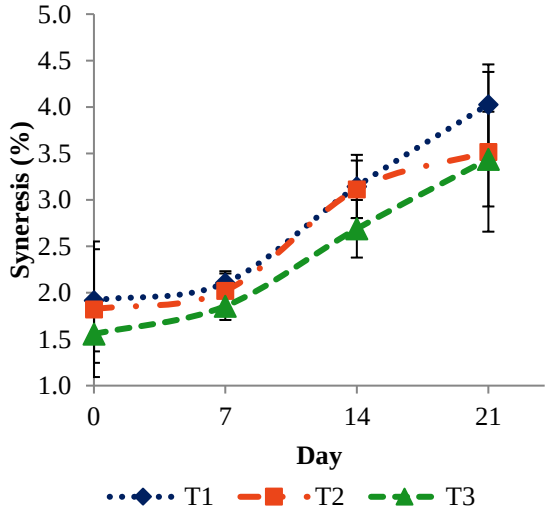

Figure 4: Variation of Syneresis of Oat Incorporated Drinking Yoghurts with Time (Mean ± SD)

Note: T1: Oat flakes of size 850-425 µm incorporated yoghurt, T2: Oat flakes of size 425-180 µm incorporated yoghurt, T3: Oat flaks of size <180 µm incorporated yoghurt

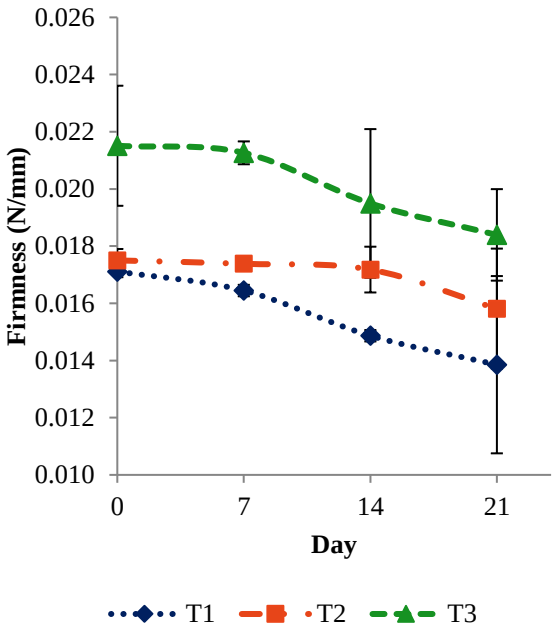

Figure 5: Variation of Firmness of Oat Incorporated Drinking Yoghurts with Time (Mean ± SD)

Note: T1: Oat flakes of size 850-425 µm incorporated yoghurt, T2: Oat flakes of size 425-180 µm incorporated yoghurt, T3: Oat flaks of size <180 µm incorporated yoghurt

Sensory Evaluation of Oat Incorporated Yoghurts

Interestingly, the four different types of yoghurt samples used in this study (C-control with no oat flakes, T1, T2 and T3) showed similar sensory attributes. Favourably, the medians of the four samples were 4 on a scale of 1 – 5 for all attributes, except sourness. The medians for sourness of T1 and T2 were 4, while those of T3 and C were 3 and 3.5, respectively. Accordingly, the purchasing intension was similar for all samples ($P=0.27$) as shown in Figure 6.

The presence of milk components retards the absorption of water and leaching out of amylose from starch granules, leading to reduced gelatinisation of oat starch [30]. However, the incorporation of instant oat flakes, which can be gelatinized easily, in yoghurt must have contributed to the favourable sensory attributes shown by the yoghurts. Unlike thermodynamically stable emulsions, kinetically stable macroemulsions like yoghurt benefit from biopolymers in the

aqueous phase for increasing the stability of the food [31-32]. Hence, the incorporation of gelatinized oat flakes most probably has led to enhancing the stability and sensory attributes of, especially, mouthfeel, texture, and overall quality of the different types of yoghurts investigated in this study.

The particle size of oat flakes exhibited minimal effects on the sensory properties of yoghurts. Also, the oat flake incorporated yoghurts showed similar properties to regular yoghurt (control) of which the thickener was gelatin. Interestingly, the intension to purchase of both oat flakes incorporated drinking yoghurts and regular drinking yoghurt was similar, indicating the potential of the functional yoghurt to enter the yoghurt market in Sri Lanka.

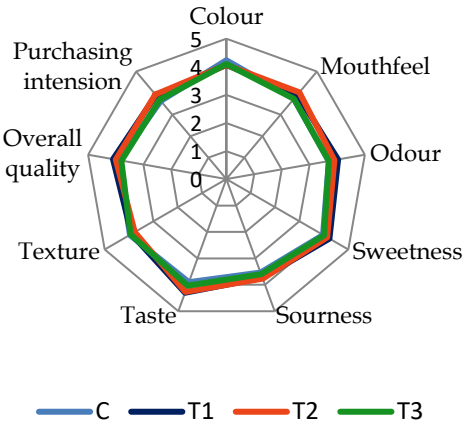

Figure 6: Mean Scores Obtained for Sensory Attributes and Purchasing Intention of Drinking Yoghurts

Note: C: Control, T1: Oat flakes of size 850-425 µm incorporated yoghurt, T2: Oat flakes of size 425-180 µm incorporated yoghurt, T3: Oat flaks of size <180 µm incorporated yoghurt

Selection of Yoghurt for Further Analysis

The type of drinking yoghurt with the largest particle size of oat flakes (T1) was chosen for further analysis, including microbiological analysis. This type of drinking yoghurt showed sensory properties similar to regular yoghurt and other types of oat incorporated yoghurts analysed in this study. The yoghurt with the smallest particle size of oat flakes (T3) was different to other types with respect to TA, TSS and firmness. However, as stated previously, the sensory attributes of T1, T2 and T3 were similar. T1 with the largest particle size range of oat flakes was chosen over T2 and T3 with smaller particle sizes of oat flakes, since the reduction of particle size requires energy [33].

Sensory Evaluation of Developed Oat Incorporated Drinking Yoghurt and Market Drinking Yoghurt

Interestingly, the sensory attributes of the selected treatment (T1) and market drinking yoghurt (M) were not significantly different except taste (Figure 7). In fact, the taste of T1 was better than that of M (*P=0.01*), with T1 and M having mean ranks of 1.73 and 1.27, respectively. The unique taste of gelatinized oat flakes appeared to have contributed positively to the taste of the oat incorporated drinking yoghurt.

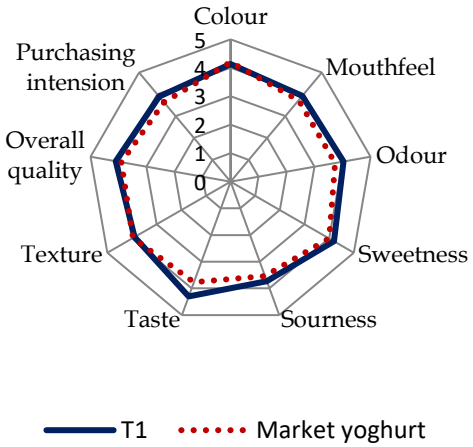

Figure 7: Mean Scores Obtained for Sensory Attributes of Yoghurts T1 and M

Note: T1: Oat flakes of size 850-42 5µm incorporated drinking yoghurt, M: Drinking yoghurt from the market

This result indicates that the oat flake incorporated drinking yoghurt may have similar or higher consumer acceptance compared to regular drinking yoghurt available in the market. However, the purchasing intension towards T1 and M were not significantly different (*P=0.14*).

Proximate Analysis

The proximate compositions of the selected oat flake incorporated drinking yoghurt (T1)

and drinking yoghurt from market (M) are shown in Table 2. The proximate compositions of the selected oat drinking yoghurt (T1) and yoghurt from the market (M) showed significant differences with respect to the moisture, protein, fat, crude fibre, total solids, carbohydrate content, ash and solid non-fat contents.

T1 was significantly lower in the moisture content than M (*P=0.000*) because of added oat flakes as a solid bulk [13]. The protein content of T1 was significantly higher than that of M (*P=0.001*) because oat, containing globulin, is a rich protein source [34]. Also, the lipid content of T1 was significantly higher than that of M (*P=0.001*) because of the high lipid content of oats. In fact, oats contain much higher levels of lipids than other cereals which are excellent sources of energy and unsaturated fatty acids [35].

The fibre content of T1 was higher than of M (*P=0.004*). Regular drinking yoghurt does not contain any trace of dietary fibre. In contrast, T1 shows the presence of fibre because polysaccharides such as cereal β-glucan, arabinoxylans and cellulose are present in oats [35]. The carbohydrate content of T1 was significantly higher than that of M (*P=0.016*) mainly due to the presence of starch in oat flakes [35]. These results indicate the higher nutritional value of oat incorporated drinking yoghurt than regular drinking yoghurt available in the market.

The ash content of oat drinking yoghurt was higher than that of M (*P=0.024*) due to the presence of bran layers and alurone layers in oat particles [36]. According to the SLS standard, SLS 824 [16], yoghurt should contain a minimum 8.0% SNF. Accordingly, both T1 and M showed SNF values above 8%. However, the SNF value of T1 was higher than that of M (*P=0.040*). These results indicate the suitability of T1 as a drinking yoghurt product.

Microbiological Analysis

Microbial analysis was carried out for drinking yoghurt incorporated with oat flakes of particle size 850 – 425 μm (T1) stored under refrigerated conditions (4-8 °C). Total plate count increased up to the 14th day after which it started to decrease (Table 3). The increment of the level of acidity, which was reflected in the reduction of pH of the medium with time, may have partly caused the reduction of bacterial growth. Also, exhaustion of nutrients in the medium may have caused the reduction of bacterial count after day 14 [37]. Thus, oat drinking yoghurt (T1), which was prepared using 300 ppm of potassium sorbate and stored at 4 ºC, is suited for consumption within 14 days from the production, according to microbiological analysis.

Table 2: Proximate Composition of Oat Flake Incorporated Drinking Yoghurt and Market Drinking Yoghurt

Parameters (%)	Oat Incorporated Drinking Yoghurt	Market Drinking yoghurt
MC	73.27 ± 0.89^{b}	80.22±0.34^{a}
Protein	4.92±0.22^{a}	2.80±0.40^{b}
Fat	6.07±0.07^{a}	3.79±0.39^{b}
Crude Fiber	0.01±0.00^{a}	0.00±0.00^{b}
Ash	0.33± 0.03^{a}	0.27± 0.02^{a}
TS	26.75± 1.76^{a}	21.22±0.31^{b}
SNF	20.67±1.78^{a}	17.43±0.61^{a}
Carbohydrate	15.40± 0.98^{a}	12.93±0.41^{b}

Note: Means with different superscripts within each row are significantly different at 0.05 level.
MC: Moisture content, TS: Total solids, SNF: Solid Non-Fat

Table 3: Bacterial Count of the Developed Drinking Yoghurt with Storage Time

Day	Total Plate Count (CFU/g)
0	9.6×10^4
7	12.0×10^4
14	9.2×10^5
21	4.8×10^5

The level of potassium sorbate can be increased up to 1000 ppm according to SLS 824 [16] to enhance the shelf-life of the drinking yogurt developed in this study.

CONCLUSIONS

The particle size of oat flakes exhibited an impact on TA, TSS and firmness of drinking yoghurt. These changes may be attributed to changes in water holding capacity, surface area and the free water activity. Nevertheless, the sensory attributes of the three oat flake incorporated drinking yoghurts were similar. The drinking yoghurt with oat flakes of the largest size range (850 – 425 µm) was chosen for comparison with the market yoghurt considering that the other yoghurts require a higher energy input for size reduction. The taste of the selected drinking yoghurt was better than that of the market yoghurt. Further, it has a higher nutritional profile than market yoghurt and can be stored microbiologically safely for 14 days at 4 ºC. These findings can be used for further development of oat incorporated drinking yoghurts.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

HD: Carried out the investigation and data curation, and wrote the manuscript. GP: Conceptualized, designed the research, supervised the study, performed statistical analysis and interpretation of data, and wrote the manuscript. AW: Designed the research and supervised the study. All authors read and approved the manuscript.

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APPLIED BIO-SYSTEMS TECHNOLOGY

Research Article **Open Access**

A Study on the Needs of Construction Labour in Sri Lanka

Kesavan Manoharan[1,2*], Pujitha Dissanayake[2], Chintha Pathirana[2], Dharsana Deegahawature[3] and Renuka Silva[4]

Abstract

Background: Human capital is a key source for the sustainable economic development of a nation. Even though past studies report a wide range of labour-related problems influencing the efficiency of labour operations in the Sri Lankan construction industry, the importance of fulfilling the labour needs has been limitedly studied. This study aims to view the current status of the fulfilment levels of needs among Sri Lankan construction labour based on the different levels of Maslow's hierarchy of needs.

Methods: A series of interviews and discussions were conducted among 70 construction supervisory workers, who had been handling a variety of labour operations in various types of construction projects in Sri Lanka. By interviewing the labourers working at their worksites and the continuous observations on their recent activities, the construction supervisors answered the fulfilment level of needs in each category of Maslow's hierarchy considering their crews. The results were then validated through a series of meetings and discussions among the engineers and construction managers.

Results: The results confirm that the physiological and safety needs are fulfilled among only three-fourths of Sri Lankan construction labourers, where the love and belonging needs are not fulfilled among 50% of them. Considering the esteem and self-actualization needs, results reported no fulfilment among more than 90% of the Sri Lankan construction labourers. The study also comprehensively identified the major causes behind the current status of the fulfilment levels of the labour needs.

Conclusions: The study highlights the significance of skills development practices for better achievement of needs and life qualities among construction labourers. Findings of this study can be used to make possible predictions on the labour needs in other foreign contexts as well.

Keywords: Construction Industry, Human Needs, Labour Motivation, Maslow's Hierarchy, Sri Lanka

[1]Department of Construction Technology, Wayamba University of Sri Lanka, Sri Lanka.
[2]Department of Civil Engineering, Faculty of Engineering, University of Peradeniya, Sri Lanka.
[3]Department of Industrial Management, Wayamba University of Sri Lanka, Sri Lanka.
[4]Centre for Quality Assurance, Wayamba University of Sri Lanka, Sri Lanka.

* Correspondence: kesavan@wyb.ac.lk

https://orcid.org/0000-0002-1985-348X

INTRODUCTION

Background of the Study

Infrastructure development and construction play a considerable role in the economic development of a country, generating a substantial amount of employment opportunities. The infrastructures can be divided into various segments, usually as transport, energy, water, environment and waste management, aero, maritime trade hub, high-rise, housing and townships, industrial cities and tourist cities. The construction industry remains as the second largest and most demanding industry in many developing countries like Sri Lanka after agriculture [1]. It involves a variety of resources such as labour, monetary, technologies, materials and equipment in different phases, namely planning, design, construction and maintenance.

The construction industry is a labour-intensive industry that heavily rely upon labour operations [2]. Labour is the most significant resource for the construction industry, since it plays a vital role in functioning construction operations connected with other resources smoothly [3]. In a typical construction project, the labour costs contribute in a range of 30-50% of the total project costs, despite the fact that these change with the type of projects in a broad range [4]. Hence, it is crucial to improve the efficiency of labour outputs in construction activities for the successful long run of an organization in the construction industry [3].

Past studies report that the construction sector of many developing countries has been experiencing productivity losses, affecting the physical progress of many construction projects [5-8]. A wide range of labour-related problems have been identified as the major issues that affect the efficiency of labour operations in construction projects [1, 9-13]. Lack of motivation of labourers is significant among those issues, especially in the construction industry of many countries [9, 11-12, 14], including Sri Lanka [2, 15-16]. Previous studies highlight several major causes resulting in a lack of labour motivation in construction projects of many countries, as shown in Table 1.

Table 1: Major Causes for the Lack of Labour Motivation in Construction

Causes	Past Studies
Low salaries and salary delays	[1, 4-6, 8, 17-25]
Lack of job security for labourers	[6, 21, 25-27]
Conflicting job policies	[7, 20, 22]
No labour rewarding mechanisms	[12, 22, 28-29]
Less welfare facilities for labourers	[19, 20, 30]
Improper promotion opportunities	[6, 18, 21]
Lack of proper incentives	[24, 31-32]

In addition, it is noted that the methods of salary payments are also another factor that has led to labourers' dissatisfaction with the organizations in the Egyptian, construction industry [13]. Work dissatisfaction has been identified among the construction labourers in many countries, including India [25], Iran [6], Nigeria [20] and Sri Lanka [8]. Notably, the labour strikes have played a major role in affecting the efficiency of labour operations in many construction projects in Indonesia, due to the work dissatisfaction of labourers [33].

Sri Lankan Context

In Sri Lanka, the post-war era has increasingly stimulated and attracted the funding bodies to invest heavily in large scale capital projects such as high-rise buildings, renovation of airports, ports, roads, highways, land reclamation, water and sanitation [30]. A great portion of the Sri Lankan construction labour comes from farming, and they work both periodical and casual on the need for specific skills in a project. Their abilities and cultural backgrounds vary in a wide

spectrum. The labour shortages and less efficiency of labour have been reported as the major problems facing the Sri Lankan construction industry in the recent scenario [8]. Consultation with industry experts has revealed that unskilled labourers work as skilled labourers in many construction projects in Sri Lanka, due to the existing shortage of skilled labourers. This affects the quality standards of work outputs and causes various problems for contractors such as high material wastage, reworks and delays. The construction firms in Sri Lanka feel this pressure more than other industries, due to the rapid expansion of the industry with the dawn of peace after a three-decades-long war. As a result, the Sri Lankan economy is gradually transitioning from a mere labour-sending economy into both labour sending and receiving economy in the local labour market [34].

Less motivation and poor skills development practices have been the major hindrances against improving labour efficiencies [2]. Studies also report that all the causes mentioned in Table 1, results in less motivation among Sri Lankan labourers in construction, influencing their work efficiency in construction operations [2, 8, 28, 30]. Considering the skills development practices, past studies report the lack of labour training facilities for the Sri Lankan labourers in construction, resulting in the absence of cognitive, soft and job-specific technical skills among labourers working in different trades of the construction industry [28, 35-36].

Though past studies have investigated various factors affecting the labour efficiencies in the Sri Lankan construction sector, those studies have not focused on the importance of fulfilling the labour needs for improving the efficiency of labour operations in construction activities. According to Central Bank of Sri Lanka [37], hundreds of thousands of labourers are working on various construction projects in Sri Lanka. Considering these aspects, this study intends to investigate the current industry's practices and community's behaviour on the fulfilment of the needs of construction labour in Sri Lanka. Further this study aspires to view the current status of Sri Lankan construction labour, based on the different levels of Maslow's hierarchy needs. This may lead the firms to upgrade their organizational policies and management practices with the awareness of the fulfilment of labour needs.

Abraham Maslow's Hierarchy of Needs

Abraham Maslow proposed the theory of human needs, which is popularly known as Maslow's hierarchy of needs in the human environment and society. Maslow's hierarchy consists of five levels of needs, namely physiological needs, safety needs, love and belonging needs, esteem needs and self-actualization needs, as shown in Figure 1.

According to Aruma and Hanachor [39], physiological needs are basic human needs that are critical for survival of humans, such as food, water, clothing, shelter, sleep as well as procreation. Safety or security needs to deal with protection and survival from messed situations, social disorder, social disturbance and physical dangers in the human environment. According to Anyanwu *et al.* [40], love and belonging indicate the need to be a part of a group such as family members, colleagues in a workplace, friends and other social groups in the society. It helps humans to have the confidence in their own abilities to contribute reasonably to the decision-making process that promotes community development in society.

According to Aruma and Hanachor [39], esteem needs are always natural, where humans seek self-respect, recognition, reputation, status and self-worth among others in their respective social groups. Self-actualization is the fifth level of needs in Maslow's hierarchy, which deals with the aspiration of humans to develop their talents and potential that are hidden in them for becoming the best that he or she is capable of being in society.

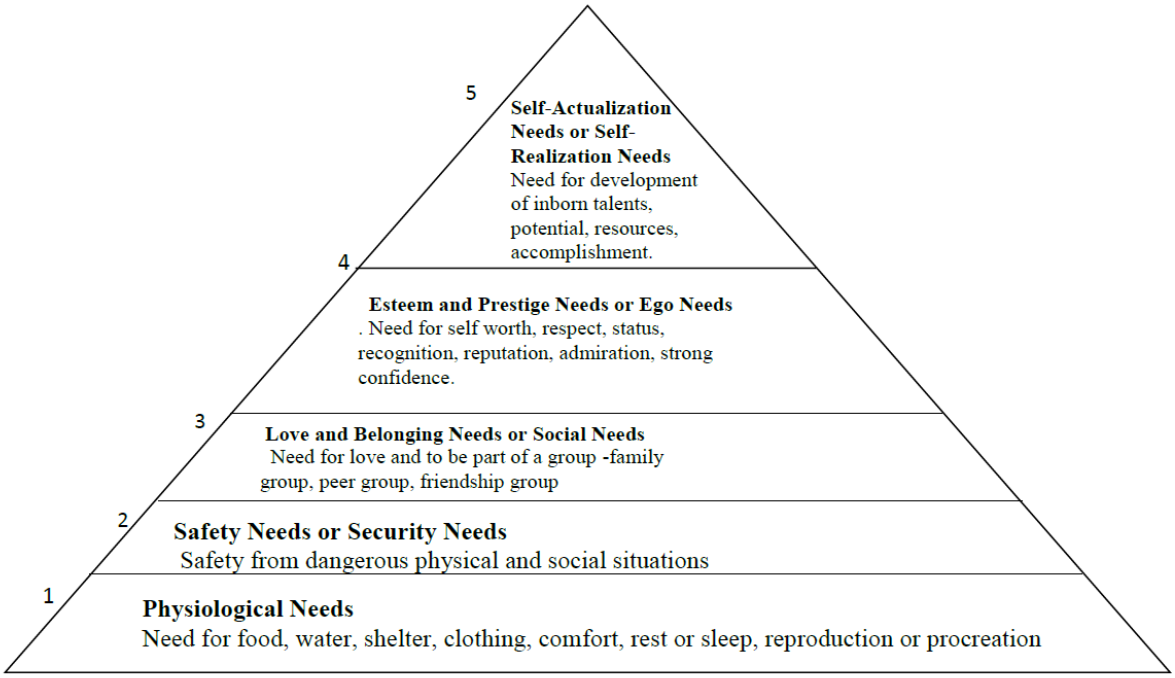

Figure 1: Abraham Maslow's Hierarchy of Needs
(Source: Onah [38])

METHODOLOGY

A series of interviews and discussions were conducted among construction supervisory workers from the Sri Lankan construction industry to view the current status of construction labour, based on the different levels of Maslow's hierarchy needs. Here, the interview respondents were the construction supervisory workers, since they are the industry workers who directly handle labour operations with continuous observations on labour behaviour. A total of 70 construction supervisory workers were selected from Sri Lankan construction projects, where the majority were handling labour operations in building projects.

Altogether, these 70 construction supervisory workers had been handling more than 500 construction labourers in various types of ongoing construction projects, including building construction, road/highway/bridge construction and water supply and irrigation work when the interviews were performed.

The construction supervisors were instructed to conduct interviews among the labourers who are directly handled by them. The interview questions were designed mainly to assess the fulfilment levels of needs among labourers considering the five categories of Maslow's hierarchy of needs. Based on the interview outcomes from the respective labourers and the continuous observations on their recent activities, construction supervisory workers decided the fulfilment levels of needs in each category of Maslow's hierarchy for their respective crews.

Considering the importance of the perspectives of engineers and construction managers in the decision-making processes related to construction management practices and organizational policies, a series of meetings and discussions were then conducted among construction experts who were the engineers and construction managers to validate the results obtained.

RESULTS AND DISCUSSION

The majority of the interviewed construction supervisors had a work experience of 6 – 10 years (30.0%), followed by 1 – 5 Years of work experience (25.0%) in the construction field. None of them had a work experience less than

1 year in the construction field, as shown in Table 2. Further, majority of them were handling building construction projects (40.0%) and road, highway & bridges projects (38.6%).

Table 2: Detailed Profile of the Interviewees

Variable	Percentage of Interviewees
Work Experience in the Construction Field	
Less than 1 Year	0.0%
1 – 5 Years	25.7%
6 – 10 Years	30.0%
11 – 15 Years	20.0%
15 – 20 Years	17.1%
More than 20 Years	7.1%
Current Working Project Type	
Buildings	40.0%
Road, Highway & Bridges	38.6%
Water Supply & Irrigation	17.1%
Dredging & Others	4.3%

The results obtained for each category of Maslow's hierarchy are shown in Figure 2. The overall results show that the basic needs, including physiological and safety needs, are not fulfilled among a quarter of Sri Lankan construction labourers, where no fulfilment was reported among half of Sri Lankan construction labourers for the belongingness and love needs. When it comes to the esteem and self-actualization needs, no fulfilment was reported for more than 90% of the labourers working in Sri Lankan construction.

Physiological Needs

Physiological needs are the needs that all humans must have met for the survival of their lives. The results show that, though the lives of majority (70%) of Sri Lankan construction labourers are with the fulfilment of physiological needs, the basic needs are not completely fulfilled for some labourers (30%), in the current scenario.

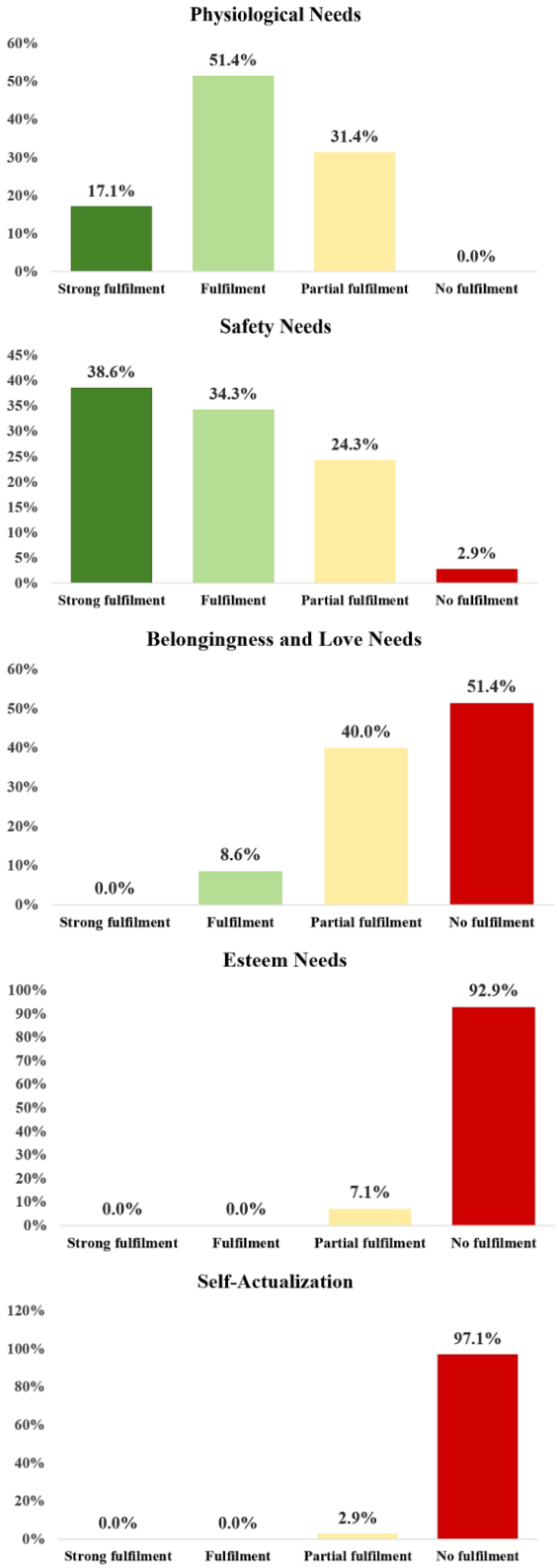

Figure 2: Fulfilment Levels of Maslow's Hierarchy of Needs among Sri Lankan Construction Labour

Previous studies have revealed that the Sri Lankan construction labourers do not get adequate salaries in some firms, and this is the major reason for those labourers' basic needs not being fulfilled at a satisfactory level [8, 27, 30, 36]. Some experts have also highlighted that most labourers who work in newly started firms have been experiencing problems related to job security, salary delays and low salary payments leading them and their families to face many economic troubles. Hence, some labourers leave their job and involve in other ways of income earning, and this has resulted in a labour shortage in construction projects in Sri Lanka. The current economic crisis of the country due to increasing inflation and recent Covid-19 pandemic lockdowns have aggravated the current scenario. Several studies have highlighted that there has been a significant difference between the salaries of Sri Lankan labourers compared to labourers working in middle-east countries [36, 41]. Al-Emad and Rahman [41] highlight the job demands for construction labourers in those countries, especially the employment opportunities for the labourers migrating from other countries, namely Chinese, Bangladeshi, Indians, Indonesians, Korean, Nepalese and Sri Lankan. Al-Emad and Rahman [41] report a significant increase in the self-motivation levels of the construction labourers working in Saudi Arabia, due to the recent improvements of incentives and salary packages resulting in better salary, which offers a better life to their families and relatives at home countries.

Safety Needs

The safety and security needs are crucial after the physiological needs of all humans for the survival of their lives in messed situations, social disturbance and physical dangers in the human environment. The results show that the safety needs are fulfilled only for three-quarters of labourers working in Sri Lankan construction projects. Considering the other one-quarter of Sri Lankan construction labourers, the interviewed constriction supervisors revealed that they have been facing some issues related to physical dangers due to various reasons, rather than any social disorders and disturbances.

Many labour injuries and accidents have been reported in many construction worksites, due to poor health and safety practices. Similar problems were also reported in other countries, including Australia [42], Egypt [7], India [14, 43], Nigeria [44] and South Africa [22]. Safe construction methods and good work conditions have a significant impact on labour morale, reducing the chances of workplace injuries along with resulting in financial liabilities and the need to take time off. Provision of health and safety trainings for labourers will be beneficial to reduce accidents and injuries in construction projects, and this can also protect the company from facing costly legal battles with the management/organization, as well as preventing labourers from leaving the job site due to work-related illnesses. In addition, the excessive workloads and uncontrolled behaviours of labourers in smoking and alcohol/drugs usage are also other facts resulting in physical dangers among labourers in the Sri Lankan construction.

Belongingness and Love Needs

Love and belonging are important for humans to have confidence in their own abilities and manage stress, leading to a decrease in the physical and mental impact of difficult times in human lives. Findings of this study reports the unfulfillment of belongingness and love needs among half of the labourers working in Sri Lankan construction projects. The experts pointed out that the labourers' soft skills related to their psychology, communication and discipline need to be improved for making more labourers to reach a satisfactory level of love and belonging from their families, colleagues, friends and other social groups in the society.

Recent studies also reported a similar need for construction labourers in Sri Lanka [28, 30]. The respondents also revealed that

the lack of focus on communication skills in school education and vocational training programmes may also be a significant factor for this. Notably, most Sri Lankan labourers working in construction sites have not completed their school education at least up to the General Certificate of Education Ordinary Level (G.C.E. O/L).

Considering the construction labourers working in other countries, Robles *et al*. [5] have reported that poor communication skills in Spanish labourers, despite their ability to adapt to changes in the environment. Meanwhile, Saravanan and Surendar [11] have stated that Indian labourers do not have a proper understanding and coordination with the other co-workers during construction operations. Having a good understanding among workers builds the construction crews strong, leading to a good relationship between the workers and employers, which results in the success of construction organizations in the long run. The psychological problems and poor discipline of construction labourers have also significantly influenced the fulfilment of belonging needs of labourers in other countries, including India [21], Nigeria [45] and Vietnam [13].

Esteem Needs

In general, humans seek self-respect, recognition, reputation and self-worth among others in their society. These play an important role in both physical and emotional well-being, leading to identifying the life goals and the direction of life status. This study reports no fulfilment of esteem needs among more than 90% of the labourers in the Sri Lankan construction industry. The respondents spotlighted that the skill shortage among Sri Lankan construction labourers under the below-listed categories is the major barrier against the fulfilment of their esteem needs.

Considering the comparison results on the work-related skills between the Sri Lankan and foreign labour forces presented by Manoharan *et al*. [36], similar situations may also be predicted among the foreign labourers, namely Chinese, Indian, Bangladeshi, Nepalese, Saudi Arabian, Malaysian and Korean.

***Transferable skills*:** Learning ability; Reading, writing and listening; Teamwork; Memorization.

***Self-management skills*:** Critical reasoning; Self-motivation; Commitment; Participation; Punctuality.

Self-Actualization

Self-actualization is the top level of needs in Maslow's hierarchy that enables humans to accept themselves and others for how they are. This is associated with multiple indicators of well-being, including greater life satisfaction, curiosity, self-acceptance, positive relationships, environmental mastery, personal growth, autonomy and purpose in life [46]. Findings of this study reports no fulfilment of self-actualization needs among more than 97% of labourers in the Sri Lankan construction. It is important to have self-confidence and positive thinking abilities to become spontaneous in thought and action.

Further, the interviewed construction supervisors reported the unavailability of these abilities among Sri Lankan construction labourers. They also highlighted that the below-listed transferable and self-management skills are required to be improved up to a sufficient level among Sri Lankan construction labourers for their achievement of self-actualization needs in future situations. Considering the comparison of the skills between the Sri Lankan and foreign labour forces presented by Manoharan *et al*. [36], similar situations can be experienced among the foreign labourers, including Chinese, Indian, Bangladeshi, Nepalese, Saudi Arabian, Malaysian and Korean.

Transferable skills: Leadership; Planning; Multiple work coordination.

***Self-management skills*:** Problem-solving; Decision making.

CONCLUSIONS

This study has reviewed the current status of Sri Lankan construction labourers based on the different levels of Maslow's hierarchy needs. The study has also identified the major reasons behind the current status of the fulfilment levels of the labour needs. It specifically spotlights the need for upgrading the current skills development practices to enable construction labourers to achieve their needs and life qualities in better ways under different categories.

Findings of this study recommend to implement necessary training facilities, rewarding mechanisms, proper incentives, promotion opportunities and welfare facilities for construction labourers at the organizational level. This may enhance securing of jobs by labourers as well as ensure the higher performance of labour operations, moving towards higher productivity, profitability and sustainability of the organizations in the long run. This study also recommends future studies focusing on skills development practices for construction labour. The overall study outcomes are expected to contribute to the possible changes in management practices and organizational policies with the awareness of the fulfilment of labour needs. Even though, findings of this study are limited to the Sri Lankan construction sector, some of these findings may also be tested in other developing countries in similar scenarios.

CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

AUTHORS' CONTRIBUTIONS

KM: Conceptualized, designed the research, carried out the investigation, performed data curation and analysis, and wrote the manuscript. PD: Supervised the study and reviewed the manuscript. CP: Supervised the study and reviewed the manuscript. DD: Supervised the study and reviewed the manuscript. RS: Supervised the study and reviewed the manuscript.

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APPLIED BIO-SYSTEMS TECHNOLOGY

Research Article **Open Access**

Mechanization of Rice Production in Anuradhapura District of Sri Lanka: Current Status and Future Potential

Wasantha Gunathilake[1*], Wasala Gamlath[1], and Nipuna Chamara[2]

Abstract

Background: Increase in productivity of agriculture has become an essential feature in stepping towards sustainability. The younger generation avoids the cultivation, leading the labour shortage to become a significant challenge. To motivate young people into agriculture, mechanization plays a vital role. Therefore, this study was conducted to identify the degree of mechanization of rice cultivation activities in the Anuradhapura district and to assess the future mechanization potential.

Methods: Primary data were collected through a comprehensive questionnaire and personal interviews. Farmers were randomly selected from the Divisional Secretariats in the Anuradhapura district based on the stratified random sampling method. Data were collected through pre-tested questionnaires from 220 rice farmers.

Results: Mechanization level was 100% in land preparation and threshing in rice cultivation. Meanwhile, highest mechanization requirement in rice cultivation was identified for bund making (100%), transplanting and weeding (97%), power chemical application (92%), and power spraying and weeding (92%). The highest mechanization capacity was reported in irrigation scheme based rice fields, while the lowest was reported under rain-fed rice cultivation.

Conclusions: Bund making, transplanting, weeding, power chemical application activities have the potential to be mechanized in Anuradhapura district, Sri Lanka. Rice transplanting approaches need to be popularized to increase the mechanical weeding, reduce weedicide application and increase mechanization.

Keywords: Anuradhapura District, Farm Machinery, Mechanization, Rice Cultivation

[1]Department of Plantation Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Gonawila, Makandura, Sri Lanka

[2]Department of Bio-systems Engineering, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Gonawila, Makandura, Sri Lanka

* Correspondence: haws.gunathilaka@gmail.com

https://orcid.org/0000-0003-2608-6212

INTRODUCTION

Sri Lanka has been an agricultural-based country for centuries. However, the agricultural sector was the least contributing subdivision to the Sri Lankan economy, with a 7.5% contribution as of 2017 [1]. Around 40% of the arable land in Sri Lanka is devoted to rice cultivation, alongwith around 26% of the labour force involved in the agriculture sector [2]. The country's agriculture mainly depends on rice production, which was responsible for 30% of employment in the country in 2005, down from 37% in 1995. The UNDP/FAO rain-fed rice research and development project, which was in operation from 1984 to 1989, proposed a new classification of rice-growing environments, which is based on the surface water source, supply, and use. According to the classification, three major categories were introduced as: rice land under major irrigation schemes; rice land under minor irrigation schemes, and rain-fed lands [3].

The history of agriculture contains many examples of using tools, but only in recent times that the highest rate of machine use has been reported. Agricultural mechanization is the application of agricultural machinery in land preparation, transplanting, irrigation, chemical application, fertilizer application, harvesting, and threshing to produce crops. Decreasing manual labour requirements is an important aspect of farm mechanization. Less labour is needed to complete the cultivation process of a mechanized farm, compared to a traditional farm. Mechanization in agricultural operations can increase the income of farmers and promote the economic interests of agriculture. Additionally, greater accuracy and higher productivity in ploughing and preparation of rice surface can lead to greater efficiency in mechanical transplanting. Further, the use of certain implements has eliminated the production procedures, which shortened the labour demand period [4].

Rice cultivation includes multiple interdependent activities to complete in a timely and efficient manner. They are land preparation, sowing or planting, harvesting, fertigation and chemigation. Land preparation includes bund preparation, primary tillage or plowing to cut, break, and invert the soil partially or completely, harrowing, or secondary tillage to cut the weed, break the soil clods, mix them, and leveling.

Bunds help to keep the irrigated water in the field and supports irrigation management. Primary tillage destroys weeds, insects, and pests, while aerating the soil [5]. Furthermore, it increases the seedbed depth, increases the water holding capacity, and improves soil health [6]. Secondary tillage further destroys immerging weeds and helps to level the seedbed. Leveling allows for the efficient application of water to conserve irrigated water, while improving surface drainage, reducing soil erosion, allowing efficient weed management, and improving crop stand and crop establishment [7].

In rice transplanting, rice is grown in the nursery, pulled, and transported to the leveled field to establish. This practice provides a higher yield, while easing the weeding. Timely fertilizer application helps to manage weeds, improve yield, and reduce fertilizer costs [5-6]. Chemigation controls weed, pests, and increase yield. Harvesting is the process of collecting mature rice grain from the crop. Harvesting activities include reaping, stacking, handling, threshing, cleaning, and hauling. Reaping is the process of cutting rice straw with a mature pinnacle above the ground. Threshing is the process of separating rice grain from the crop. Cleaning involves separating useful rice with unwanted substances including immature grain, stone, and straw [7].

Understanding the status of mechanization level in Sri Lankan rice cultivation is essential to introduce improved and efficient mechanized solutions. Mechanization is essential to face the skilled agricultural labor shortage, while establishing

food security in the country. Therefore, this survey was planned to understand the status of mechanized rice cultivation in Sri Lanka. The general objective of this study was to identify the degree of mechanization of rice cultivation activities in the Anuradhapura district, with an emphasis on the level of mechanization, mechanization capacity, power per unit area, while evaluating the future mechanization potential.

METHODOLOGY

Location

This study was carried out in Anuradhapura District from June to September in 2018. Anuradhapura is one of the major rice cultivation districts and reported the highest rice production (365,988 MT) during the 2015/2016 *Maha* season, accounting for about 13% of the rice production of the country [8].

Sampling and Data Collection

The stratified random sampling approach was used in sample collection. Data were collected through a pre-tested questionnaire from 220 rice cultivation farmers from randomly selected Gramaniladhari divisions of 22 Divisional Secretariats of Anuradhapura district. The structured questionnaire was pre-tested using 15 rice farmers. In the survey, nine rice cultivation steps were focused as: Land preparation (LP), Bund Making (BM), Seedbed preparation (SB), Transplanting (TP), Weeding (WD), Power Weedicide Application (PWA), Power Pesticide Application (PPA), Harvesting (H) and Threshing (T).

Data Analysis

Mechanization Level

The following index (Equation 1) was used to determine the ratio of mechanized operations at different agricultural stages, separately [5].

$$ML = \frac{AM}{AC} * 100 \quad (1)$$

Where,

ML : Mechanization Level (%)
AM : Mechanized Cultivated Area (ha)
AC : Total Cultivated Area (ha)

Power per Unit Area

This Index (Equation 2) shows the average power available per unit of cultivated agricultural land. The unit used to describe this index is horsepower per hectare ($hpha^{-1}$) [9].

$$PPA = \frac{PA}{AC} \quad (2)$$

Where,

PPA : Power per Unit Area (hpha-1)
PA : Total Machinery Power (hp)
AC : Total Cultivated Area (ha)

Labour Capacity

Operations carried out exclusively by human power were determined by using the Equation 3 [9].

$$LC = 0.1\ H\ \frac{TH}{AC} \quad (3)$$

Where,

LC : Labour Capacity (kWh ha^{-1})
0.1 : Human Power in (kW)
H : Number of Operators
T :Time devoted to Manual Operations (hours)
AC : Total Cultivated Area (ha)

Mechanization Capacity

The mechanization capacity that corresponds to the use of machinery with mechanical energy sources under direct human control, was evaluated using the Equation 4 [9].

$$MC = RP\ \frac{TM}{AC} \quad (4)$$

Where,

MC : Mechanization Capacity (kWh ha^{-1})
RP : Rated Power of Machines (kW)
TM : Time Used (hours)
AC : Area of Land (ha)

Mechanization Index

Mechanization Index (Equation 5) is the ratio of mechanical energy used by rice machines over the total farm operational energy including human labour and mechanical energy [10].

$$MI = \frac{MC}{(MC + LC)} \quad (5)$$

Where,

MI : Mechanization Index (kWhha-1)
MC : Mechanization Capacity (kWh ha^{-1})
LC : Labour Capacity (kWhha^{-1})

Mechanization Requirement

This index was calculated using the simple mathematical relation, as shown in Equation 6 for each agronomical operation [9].

$$MR = 100 - ML \quad (6)$$

Where

MR : Mechanization Requirement (%)
ML : Mechanization Level (%)

RESULTS AND DISCUSSION

The important indicators for power per unit area and mechanization level were computed to determine the level of mechanization of rice fields in the Anuradhapura district. The mechanization level of land preparation in all Divisional Secretariats of Anuradhapura district was 100% (Table 1).

Farming operations generally include energy-intensive and control-dependent operations. The importance of timely land preparation and cost-intensiveness of manual land preparation have led to the popularization of mechanical land preparation in the entire district. However, any type of mechanical process was not used in the preparation of bunds (Table 1). As no other alternative method has been developed to fulfill bund preparation, new machinery is required to be designed, developed and evaluated to mechanize the bund preparation in rice land preparation [8]. The average mechanical seedbed preparation in the Anuradhapura district was 30% (Table 1). People who owned tractors denoted a higher tendency of seedbed preparation.

Fully mechanical transplanting is very efficient in large plots than in small plots, because maneuvering the machine over bunds or in irregular shaped plots is difficult compared to larger plots. The average level of mechanization for rice transplanting was 3% in the Anuradhapura district. Among surveyed Divisional Secretariats, only farmers in Rajanganaya had adopted mechanical transplanting at a notable level of 56%. The small size of the rice fields, high cost of rice transplanting associated with machine renting and fuel, technical issues associated with their operating, unskilled labor, lack of efficient transplanting experience, and problems in the preparation of seedlings were identified as the major barriers for mechanized rice transplanting.

There are three weeding methods available in rice cultivation as chemical weeding, manual weeding, and mechanical weeding. Manual and mechanical weeding reduce the chemical cost and is environmentally friendly. However, manual and mechanical weeding is possible only in row-planted rice fields. Therefore, mechanical weeding was reported by only the farmers, who had followed rice transplanting. However, mechanical weeding is not possible within the crop rows and is limited to plants with 2-4 leaves. However, mechanical weeding is less labor-intensive than manual weeding, but difficult to be practiced in hardened soil or less water available soil.

The average mechanization level for rice weeding in the Anuradhapura district was also very low (3%). This concluded that mechanized rice weeding technically depends on the mechanization of transplanting. Therefore, transplanting should be mechanized before mechanizing the rice weeding operations. Table 1 shows the mechanized weeding and mechanized transplanting levels among the farmers in the Rajanganaya Divisional Secretariat as 56% and 56%, respectively.

The average power sprayer usage level in the Anuradhapura district was 9% (Table 1). These Divisional Secretariats are fed under major irrigation systems and the

Table 1: Mechanization Level (%) of Various Farming Operations in Rice Fields of Anuradhapura District

Divisional Secretariat	Mechanization Level (%)								
	Land Preparation	Bund Making	Seedbed Preparation	Transplanting	Weeding	Weedicide Application (Power Sprayer)	Pesticide Application (power Sprayer)	Harvesting	Threshing
Epologama	100	0	23	0	0	0	0	100	100
Galenbidunuwewa	100	0	25	0	0	0	0	100	100
Galnewa	100	0	33	0	0	23	23	100	100
Horowpathna	100	0	30	0	0	0	0	96	100
Kebithigollewa	100	0	19	0	0	0	0	100	100
Kahatagasdigiliya	100	0	27	0	0	0	0	73	100
Kekirawa	100	0	32	0	0	0	0	100	100
Medawacchiya	100	0	42	0	0	0	0	89	100
Mahavilacchiya	100	0	53	0	0	0	0	95	100
Mihinthale	100	0	0	0	0	34	34	97	100
Nacchaduwa	100	0	17	0	0	0	0	100	100
Nocchiyagama	100	0	29	0	0	24	24	100	100
Nuwaragampalatha East	100	0	21	0	0	21	21	100	100
Padaviya	100	0	42	0	0	16	16	100	100
Palagala	100	0	39	0	0	0	0	100	100
Palugaswewa	100	0	35	0	0	0	0	94	100
Rabewa	100	0	29	0	0	0	0	100	100
Rajanganya	100	0	44	56	56	23	23	100	100
Nuwaragampalatha Central	100	0	26	0	0	16	16	100	100
Thalawa	100	0	21	0	0	7	7	100	100
Thirappane	100	0	38	0	0	0	0	100	100
Thabuththegama	100	0	30	0	0	21	21	100	100
Average ML	100	0	30	3	3	8	8	97	100
Average MR	0	100	70	97	97	92	92	3	0

average land size of above Divisional Secretariats are higher than that of others. Most farmers were using manual knapsack sprayers for chemical application. The high price of power sprayers also demotivates the development of mechanization options for power sprayers. The average mechanization level of rice harvesting operation was desirable at 98.8% (Table 1). The pre-harvest losses due to pests and unfavourable weather conditions on extended over maturity and high cost of manual harvesting have contributed to the mechanization of harvesting [9]. The mechanization level of land preparation in all Divisional Secretariats was recorded as 100% (Table 1).

Power per Unit Area

The power per unit area for land preparation was 42.1 hpha^{-1}. Two-wheel tractors and four-wheel tractors were mostly used for land preparation. However, no power-generated machines were used for bund preparation. The highest power value per unit area was for threshing (87.3 hpha$^{-1)}$. Low power values per unit area were recorded in transplanting as 4.3 hpha^{-1}, weeding 1.9 hpha^{-1}, and power sprayer for chemical application as 0.3 hpha^{-1} (Table 2).

Mechanization Capacity

The highest total mechanization capacity of 58660.9 kWhha^{-1} (Table 2) was recorded inrice fields cultivated under major irrigation systems, followed by minor irrigation systems (19839.4 kWhha^{-1}). The rain-fed irrigation system reported the least total mechanization capacity as 15216.2 kWhha^{-1}, due to the low amount of land extent compared with the major and minor irrigation systems.

In major irrigation systems, transplanting and mechanical weeding accounted for 6.1 kWhha^{-1} and 2.8 kWhha^{-1} machine capacities, respectively. Meanwhile, zero machine capacity was recorded in minor and rain-fed rice cultivation systems. The machine capacities for power weedicide application in major and minor irrigation systems were 92.0 kWhha^{-1} and 7.7 kWhha^{-1}. However, there a Zero mechanization capacity for power weedicide application was observed in rain-fed irrigation systems.

Machine capacities for power pesticide application were 45.1 kWhha^{-1} and 3.0 kWhha^{-1} in rice fields under major and minor irrigation systems, respectively. Similar to the transplanting and mechanical weeding zero machine capacity was recorded for power pesticide application also in the rain-fed rice cultivation systems. The mechanization capacity of rice fields under major and minor irrigation systems were notably different from the rain-fed rice cultivation systems. Low mechanization levels for rice transplanting and weeding were observed in rainfed rice cultivation systems, compared with other agricultural operations, highlighting the need for more attention.

As shown in Figure 1, the mechanization capacity of major irrigation scheme based rice fields were found to be 58660.9 kWhha^{-1}, followed by 19839.4 kWhha^{1} and 15216.15 kWhha^{-1} for the minor irrigation scheme based rice cultivation and

Table 2: Mechanization Capacity of Rice Fields under Different Irrigation Systems and Power per Unit Area of Anuradhapura District

Step	Major Irrigation	Minor Irrigation	Rain Fed	PPA (hpha^{-1})
	MC kwhha^{-1}	MC kwhha^{-1}	MC kwhha^{-1}	
LP	31214.6	8197.06	4928.29	42.07
BM	0	0	0	0
SBP	623.23	394.67	162.38	26.51
TP	6.06	0	0	4.32
MW	2.79	0	0	1.85
PWA	92.03	7.73	0	.0.22
PPA	45.07	3.04	0	0.25
T	26677.08	11236.93	10125.48	87.29
Total	58660.85	19839.43	15216.15	

Note: LP: Land Preparation, BM: Bund Making, SBP: Seed Bed Preparation, TP: Transplanting, MW: Mechanical Weeding, PWA: Power Weedicide Application, PPA: Power Pesticide Application, HV: Harvesting, T: Threshing

rain-fed rice cultivation systems, respectively. Rice fields under major irrigation systems represented a relatively higher amount of mechanization in rice cultivation, due to higher land extant/farmer, high labour intensity, and limited time for seasonal cultivation.

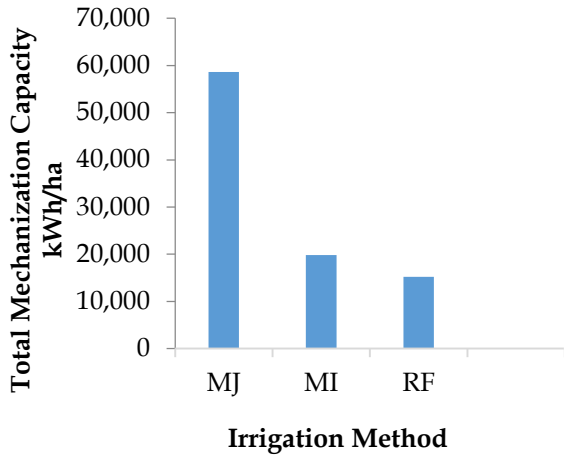

Figure 1: Total Mechanization Capacity under Irrigation System (kWhha^{-1})
Note: MJ: Major Irrigation, MI: Minor Irrigation, RF: Rain Fed

Mechanization Index

The highest mechanization index of 99.4% was determined for threshing, followed by land preparation (96.1%) indicating that such machinery has already reached the farmer-friendly level of mechanization (Table 3). The mechanization index of 7.0 and 1.6 for transplanting and power spraying, respectively indicated that such machinery has not reached the farmer-friendly level of mechanization, reflecting the need of introducing user-friendly and economically feasible machinery in such operations in rice cultivation.

Table 3: Mechanization Index

Cultivation Steps	MI(%)
Land Preparation	96.1
Transplanting	7.0
Chemical Application	1.6
Threshing	99.4

Note: MI: Mechanization Index

Mechanization Requirement

The mechanization requirement (MR) for different operations in rice cultivation in the Anuradhapura district was computed based on the current mechanization level of each operation. As the mechanization level of threshing and land preparation is almost 100%, the mechanization requirement of land preparation and harvesting equals zero (Table 4).

Table 4: Average Mechanization Requirement in the Anuradhapura District

Cultivation Steps	MR
Land Preparation	0
Seed Bed Preparation	70
Bund Preparation	100
Transplanting	97
Weeding	97
Power Spraying	92
Threshing	0
Harvesting	3

Note: MR: Mechanization Requirement

Due to the lower mechanization levels of transplanting and weeding, the highest mechanization requirement was reported for those operations as 97%, followed by power spraying (90.9%) and seedbed preparation (70.3%). This data underlines the insistence of removing barriers for the development of mechanization of rice weeding in the Anuradhapura district.

Labour Capacity

In computing the labour requirement on cultural steps, the ploughing was done only using tractors consuming 7 labour hours per hectare (Table 5). The mechanical seedbed preparation by tractors needed 3.5 labour hours, while 42 labour hours were required for manual seedbed preparation. Still, there are no machines developed for bund making in the Anuradhapura district thus, an average of 150 labour hours was required for one ha of rice land. The manual seed sowing (broadcasting) required an average of 49 labour hours per hectare of rice land.

Table 5: Average Labours and Machine Requirements for Mechanical and Manual Cultivations per Hectare

Steps	No of Labours	Mechanical Cultivation		Manual Cultivation	
		Type of Machines	Hours	No of Labours	Hours
PG	1	Tractor	7	-	-
SB	1	Tractor	3.5	6	7
BM	-	-	-	10	15
SS	-	-	-	7	7
TP	2	Transplanter	6	16	8
WD	1	Weeder	4.5	-	-
CA	1	Power Sprayer	2.5	1	6
HV	4	Combine Harvester	4.5	12	7
TH	4	Combine Harvester	4.5	-	-

Note: PG: Ploughing, SB: Seed Bed Preparation, BM: Bund Making, SS: Seed Sowing, TP: Transplanting, WD: Weeding, CA: Chemical Application, HV: Harvesting, TH: Threshing

The highest labour saving was found in mechanical transplanting, which required only 12 labour hours per hectare, while manual transplanting needed 128 labour hours for the same. The ability to maintain a uniform seedling spacing in mechanical transplanting, which facilitates mechanical weeding is an additional advantage.

The availability of effective sunlight by uniform plant spacing may enhance the higher tillering ability and unfavorable conditions for pests, reducing the cost for pest control. The power sprayer requires only about 2.5 labour hours per hectare, while manual spraying required around 6 hours. The labour requirement of 84 hours for manual harvesting followed by threshing has been reduced by the use of combine harvesters to 18 hours, due to simultaneous harvesting and threshing operations.

CONCLUSIONS

Results of this research indicated that except for tillage and threshing operations, a considerable gap is found in the current mechanization level resulting in the mechanization requirement of other operation steps. The mechanization level, mechanization capacity, and power per unit area for transplanting, weeding, power spraying denoted a very low value. There were no bund-making machines used in the Anuradhapura district. A zero mechanization capacity was reportd for transplanting and weeding in minor and rain-fed irrigation systems. Meanwhile, a zero machine capacity was recorded for power pesticide application in the rain-fed rice cultivation systems.

Mechanization of transplanting fascilitates the mechanization of weeding, while reducing the weedicide usage. This will be a solution to the agricultural labor shortage issue also. However, plot sizes need to increase to enable transplanting, which increases the demand for mechanized bund-making. The highest mechanization requirement was found to be 100% for bund making, followed by 97.1% for transplanting and weeding. The power spraying and seedbed preparation also required high mechanization requirements of 90.9% and 70.3%, respectively. Bund making, transplanting, weeding, power chemical application in comparison with other agricultural operations are uncomplimentary and require more attention than the other agronomic operations.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

WG[1]: Designed the research, supervised the study, interpreted the data, and wrote the manuscript. WG[2]: Collected the data and wrote the manuscript. NC: Supervised the study and reviewed the manuscript. All authors read and approved the manuscript.

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APPLIED BIO-SYSTEMS TECHNOLOGY

Research Article **Open Access**

Farmers' Willingness-to-Pay (WTP) for Water Quality Improvements: Insights from Anuradhapura District of Sri Lanka

Dulanjana Hansini, Menuka Udugama* and Piyumi Ranadewa

Abstract

Background: Tanks and reservoirs play a significant role in the livelihood of the farmer households in the Anuradhapura district. Over the years, these tanks have been abandoned due to pollution and other socio-economic and political activities. As a result, the villagers lack access to adequate quality water supply. Inadequate estimation of tanks' true value as a multipurpose resource is the key reason behind poor management. Therefore, this study aims to elicit the Willingness-to-Pay (WTP) for water quality improvements of the tanks in the Anuradhapura area.

Methods: Data were collected from a sample of 120 randomly selected farmer households living adjacent to small tanks. A choice experiment was used to elicit the WTP and the preferences for water quality improvement in small tanks.

Results: Results revealed that respondents are willing to pay 10% of the monthly income generated from tank related activities, as a payment for quality improvement. Further, the level of water quality improvements had a significant positive impact on people's WTP, while the reduction of fertilizer level, fine and the payment were not significant. About 85% of the respondents were willing to pay Rs.100.00 as the service charge for tank water quality improvement, mainly as they believe tank management to be their responsibility as a community.

Conclusions: Study highlights the importance and community contribution for small tank rehabilitation programmes in the Anuradhapura District.

Keywords: Choice Experiment, Small Tanks, Water Quality Improvement, Willingness-to-Pay

Department of Agribusiness Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Gonawila, Makandura, Sri Lanka

* Correspondence: menukaudugama@gmail.com

https://orcid.org/0000-0001-7692-8698

INTRODUCTION

Tanks in Sri Lanka, which store and provide irrigation water, mainly to the dry zone, is one of the oldest water harvesting and management systems in the world. Water is a social good, which should be affordable to the poor. In ancient times, water was an ample resource and treated as a free good. Many people living in rural areas and developing countries lack access to an adequate water supply, and in many parts of the world water resources are poorly managed [1]. Even with the rising population and economic growth, it remains the same [2]. The high population and economic growth lead to accumulation of pollutants in water bodies. As a result, many rivers and groundwater sources have become polluted and water has now become a scarce resource [2].

In the dry zone (DZ) of Sri Lanka, the annual average precipitation is low compared to the wet zone and also, the evaporation rate is higher in the dry zone. Therefore, ancient kings built tank systems to enhance the sustainability of water and prosperity of the country. Those cascade systems traditionally named "Ellanga" were built to maintain the water resources in DZ and they are interconnected systems of small tanks. Even today, most of our rural people use these tanks mainly for irrigation. Groundwater resources in the country are estimated at 7,800 million m^3 and it is the major source of water, especially in rural areas. It's estimated that around 72% of the agricultural population relies on groundwater for domestic use [3]. Further, these tanks provide various kinds of indirect and direct services to the people and nature [4].

In ancient time, livelihoods were environmentally friendly, which maintained the sustainability of the natural environment. The farmers had to obey the rules imposed by the king to maintain the quality of tanks and water. Because of these rules and supervision of the government officers of the kingdom, the repairs, maintenance and management of tanks went smoothly and ensuring long-term sustainability. Because of tanks related traditions and customs, the people who lived around the tanks guaranteed the quality of the tanks and water.

After the abolishment of kingdoms, several Departments and Boards hold the responsibility for the maintenance of tanks. But due to various reasons like political instabilities, over exploitation, lack of maintenance and waste accumulations these tanks are now in need of being rehabilitated. Nowadays, most of the tanks are abandoned because of the deterioration of the water quality in tanks. To overcome the negative effects of water scarcity, water quality must be maintained and improved effectively and efficiently. Due to various socio-economic and political reasons, the maintenance of small tanks has been neglected for a long period of time. Key stakeholder participation is crucial for effective and efficient management [5]. Also, a proper valuation will ensure efficient utilization of water [2]. Water pricing is an effective mechanism to manage water use [6]. Payment for water brings an ownership feeling to the farmers [7], which will ultimately lead to better use of available water and increased crop production.

Recent publications have provided valuable insights into the valuation of water quality improvements all over the world. According to their studies, Willingness-To-Pay (WTP) is affected by the bid price as well as the household's income, education, gender, time spent to fetch water, water treatment practice, quality of water, expenditure on water and age of the respondent [2, 8-9]. The household's WTP for water quality restoration of Sampaloc Lake in San Pablo City within the Philippines has been estimated to be PHP 177.09 /household or PHP 7,102,017/year for the whole number of households [9]. Based on their estimations, the households' WTP is affected by the bid price as well as the household's income, willingness to participate in lake management programmes. Hite *et al*. [10] found that public support exists for water quality

improvements and the inclusion of debriefing questions could be effectively used to refine WTP estimates in contingent valuation studies. Therefore, findings of such studies have important implications for programmes to market environmentally friendly agricultural practices. According to an economic valuation study conducted in Yunnan, China, the estimated WTP for water quality improvement by one grade level is roughly like 3% of the typical household income. This study also provides an analysis of the extent of water quality improvements [6].

Hearne and Torpen [5] have studied the stakeholder preferences for water management alternatives within the "Red basin" in Canada to estimate the WTP for extra water management programmes. An equivalent study was conducted by Imandoust and Gadam [11] for the Pavana River in Pune, India to seek out people's WTP for improvement of river water quality using the contingent valuation method. The important variable during this sort of contingency valuation method study is income, which has a positive relationship with WTP. The mean WTP was estimated as Indian Rs 17.6 per family per month (Imandoust and Gadam, 2007).

The Households' WTP for improved rural water service provisioning in Eastern Ethiopia has estimated to be USD 3.72 [2]. Consistent with their findings household income, education, sex, time spent to fetch water, water treatment practice, quality of water and expenditure on the water have shown positive and significant effects on WTP for improved water service provision, while the age of the respondent has featured a negative and significant effect. Since most of the people within the world care about their health, people are more curious about the standard of beverage. Therefore Kwak *et al.* [12] focused to live the economic benefits of water quality improvement through a case study on Pusan, Korea. The results revealed that the monthly mean WTP estimate spike model was KRW 2,124.3 (USD 1.72) per household.

In Sri Lanka, a limited number of studies have been conducted to assess the WTP for water quality improvement. Shantha & Ali [13] have attempted to study the value of irrigation water and identify the most factors behind the WTP decision. The results indicate a universal incontrovertible fact that the degree of scarcity of common-pool resources guides to work out the worth of such resources. One among the foremost important policy implications of this study is that the possibility of restructuring the prevailing freed from a charge irrigation system by taking under consideration the value of irrigation water. When considering the studies associated with the economic valuation of water in Sri Lanka, Sivarajah and Ahamad [14] have investigated the economic valuation of irrigation water under a serious irrigation scheme (*Gal Oya*) in Eastern Sri Lanka. This study has estimated the worth of irrigation water using the principle of Marginal Value Product, through an applied mathematics approach that maximizes net returns for a selected farm plan. The results indicated that the value of irrigation water was Rs. 6,699.2, the quantity by which internet returns might be increased by its additional usage. The analysis focuses on the *Kirindi Oya* irrigation system, located in South-Eastern Sri Lanka, and has broader implications for other multiple-use systems. The ultimate result indicates the mixture value of water in agriculture is bigger than it is for domestic uses [15]. A study conducted by Renwick has valued the water usage of a multiple-use system (irrigated agriculture and reservoir fisheries) to demonstrate the importance of accounting for alternative uses of irrigation water by examining the economic contribution of agriculture, a recognized consumptive water use, and reservoir fisheries, an unrecognized non-consumptive water use.

To value the connection of the piped water network in South-West Sri Lanka, a

hedonic price analysis has been conducted by Berg and Nauges [16], under the title of "The WTP for access to piped water: a hedonic analysis of house prices in South-West Sri Lanka". The findings reveal that the Willingness-to-Pay for a piped water connection is around 5% of monthly household expenditure, which is at the lower end of the range from estimates obtained in case studies in other developing countries. Therefore, the WTP for piped water decreases as a proportion of income when income goes up. Jayasekara and Gunawardena [17] have studied a contingent valuation approach for Bolgoda lake, and the estimated WTP values per household per month for the heavy dependency group were LKR 1,550.00, while for the less dependency group was LKR 514.30. Meanwhile, Aheeyar [18] has revealed that farmers are willing to pay Rs. 599-890 (US$ 6-9) per/ha/year in addition to the current level of resource mobilization to ensure the long-term sustainability of infrastructure and to achieve improved irrigation services. Today Sri Lanka is badly experiencing the threat of silting in reservoirs [19].

There is a scarcity of studies administered on the valuation of water quality in Sri Lanka [17] and a proven gap exists in knowledge about WTP for tank water quality improvements in Sri Lanka. Most of the research projects associated with the valuation of water in Sri Lanka so far specialise in either irrigation water uses or domestic water uses. Based on the highlights of a study conducted by Bogale and Urgessa [2], the failure to take care of the water quality level in tanks may end in inefficient and inequitable water allocation decisions. Access to safe water also supports economic process and supply income benefits for both households and government. This may result from a discount within the costs of health treatment and gains in productivity [20]. The lack of recognition of a tanks' true value as a multi-purpose system and poor social involvement are the key reasons behind poor maintenance. Therefore, this study aims to fill this gap by assessing the preference for sustainable management of small tanks. The specific objective is to elicit the WTP for water quality improvements of the tanks in the Anuradhapura area.

METHODOLOGY

Location and Sample Selection

Anuradhapura is an ancient city that is mainly based on an agricultural economy, and hence, most of the country's tank systems are located in the Anuradhapura district. Most of the people in this area utilize this tank system for their daily use. A sample of 120 farmer households was randomly selected for the survey, from the Thambuttegama Divisional Secretariat Divisions. Additionally, the necessary data were collected from focus group interviews and literature to determine the relevant attributes including payments and community water resources.

Method of Valuation

In developing countries, the choice experiment method is a powerful tool to measure the economic benefits of non-market goods like improved water services [2]. There is much literature on the application of the choice experiment for water quality improvement all over the world [17, 21-22]. Therefore, a choice experiment was adopted to estimate farmers' WTP for water quality improvement.

Choice Experiment

Choice experiment is a stated preference technique that allows analysts to assess preferences and estimate WTP from respondents' responses to a hypothetical market solicitation. Choice experiments are based upon two theoretical foundations, Lancasterian consumer theory and random utility theory. Lancasterian theory posits that utility is derived from the attributes of a particular product. Random utility theory posits that individual utility (U) is unknown, but can be decomposed into a systematic or deterministic component (V) and an unobserved or stochastic component (ε).

Thus, for individual *j* in scenario *i*, utility can then be expressed as,

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad [1]$$

Where,

U_{ij} : Total utility from alternative *i* by individual *j*
V_{ij} : Explainable component with the assigned attributes
ε_{ij} : Error component

In this study, there are several attributes related to water quality. Therefore, choice modelling approach is used because it is the most appropriate approach to measure the WTP of consumers in multidimensional cases. There is much literature on the application of choice modelling for an estimated WTP for water quality improvement [22-24].

Questionnaire of the Survey

The inclusion of debriefing questions can be used to refine WTP estimates in choice experiment studies [10]. Focus group discussions were carried out with government officials and respondents before designing of the experiment. Thereafter, a pilot-study was conducted with 15 respondents to validate the questionnaire and the choice experiment.

The questionnaire included three sections and it was designed to focus on how respondent values the water quality improvements. Through the initial part of the questionnaire, demographic data were explored. Gender, age, education level, and income levels were collected as demographic data. The questioning formats, such as dichotomous questions and open-ended questions, were used to explore the demographic characteristics of the respondents. Demographic questions were used to understand the reasons for their behaviour on water quality improvements.

The second part of the questionnaire includes questions regarding current water sources, tank water usage, alternative water sources, respondents' judgments of water quality levels, the extent to which water to improve, uses of tank etc. Finally, the questions of WTP for water quality improvement of tanks and willingness to contribute to manage the tanks were explored.

Choice Cards

The attributes and levels of the choice experiment were finalized after successful personal interviews and literature surveys as shown in Table 1. The selected attributes were arranged into choice cards by using a fractional factorial design for convenience [5]. The respondents were asked to choose the option they prefer the most in a water quality improvement programme from the choice cards, as shown in Table 2.

Table 1: Attributes and Levels

Attributes	Levels
Water quality	Increase clarity/transparency
	Reduce *Salvinia* and other invasive aquatic plants
	Maintain current quality
Fertilizer/ Chemicals reduction	25% less
	50% less
	Current level
Payment	5% of the total income per month
	10% of the total income per month
	Current amount
Fine	One month payment + Rs. 100.00
	One month payment + Rs. 200.00
	Current amount

Statistical Analysis

The results of the survey and choice cards were coded and analysed using Stata software. Following the standard practice in the choice experiment literature [5,22], a Conditional Logit (CL) model was used to

Table 2: Designed Choice Card

Attributes	Option 1	Option 2	Status Quo
Water quality	Reduce Salvinia & other invasive plants	Increase clarity / transparency	Maintain the current quality
Fertilizer level	25 % less	50 % less	Do not like to reduce the fertilizer level
Payment	10 % of the total income per month	5 % of the total income per month	Current payment
Fine	One month payment + Rs. 200.00	One month payment + Rs. 100.00	Current payment

analyse the data. The model is given in Equation 2. A linear random utility model was employed for the econometric specification. The general form of the CL model includes attributes as a linear summation in the following general form:

$$V = \beta_0 + \beta_1 X_{water\ quality} + \beta_2 X_{fertilizer\ level} + \beta_3 X_{payment} + \beta_4 X_{fine} + \varepsilon \quad [2]$$

Where,

X : Attributes associated with relevant alternative

β : Coefficient vector of the attributes

ε : The error component.

RESULTS AND DISCUSSION

Descriptive Analysis of Survey Data

According to the table 3, a total of 120 households were interviewed and from the respondents 73.3% are males and 26.7% are females. In the households, often male respondents are willing to participate and provide information. After all, they are mainly engaging with a tank, because they use tank water for agriculture. The average age of the sample is 54 years and it was a benefit because the information gained from the respondents are enriched with their experience as they have been observing the tanks for years.

All the respondents are year-round residents with an average household size of 4 – 5 members. The majority of respondents (40%) are educated up to O/L.. Therefore, the literacy rate of the respondents is high even though there were no graduates or diploma holders. But 10% of the sample did not receive a school education, since they engage with agriculture without going to school. When considering the income dispersion of the sample, most of the respondents (56.7%) have an income that lies between Rs. 25 000 – Rs. 50 000 and a considerable amount of the respondents received an income between Rs.50 000 – Rs. 75 000 per month. No one gets more than Rs. 75 000 as monthly income.

About 93.3% of respondents live from agriculture, while only 6.7% rely on non-agricultural income sources like selling lotus flowers collected from the village tanks. All most all the respondents are members of farmer associations and pay an average membership fee of Rs. 379.31 per month. All respondents use the village tanks as one of the current water sources. When considering the uses of the tank, the majority of households use tank water for agriculture (87%) and livestock activities (50%). No one used tank water for drinking, bathing, industries, and domestic uses. For drinking and other household uses, most of the respondents tend to use wells and tap lines.

Table 3: Descriptive Analysis of Survey Data

	Level	Percentage (%)
Gender	Male	73
	Female	27
Family size	2 Members	6.7
	3 Members	6.7
	4 Members	33.3
	5 Members	33.3
	6 Members	10
	7 Members	6.7
	8 Members	3.3
Educational Level	Graduate	0
	Diploma holder	0
	A/L	30
	O/L	40
	Pass grade 8	20
	No	10
Income Dispersion	<Rs.25000	3.3
	Rs.25000 – Rs.50000	56.7
	Rs. 50001 – Rs.75000	40
	>Rs.75000	0
Income source	Agriculture	93.3
	Non-agriculture	6.7

Note: N: 120

The respondents stopped using tank water for drinking and other domestic uses, because the tank water was polluted severely by invasive aquatic plants and chemicals. The respondents rated water for agriculture as the most important benefit of tanks, while using for fishing as the least important benefit.

WTP for Water Quality Improvements

When considering the uses of the tank, the majority of households use tank water for agriculture and livestock activities because the current water quality was not much affected for agriculture and livestock activities. The respondents highlighted that villagers move away from drinking tank water, since they found out about the kidney damages due to the water in the area. The respondents rated water for fishing as the least important benefit by indicating that the fish harvest is low in the tanks as the fish population decrease due to the hazardous chemicals accumulated in the tank. The water used for livestock rated as the second most important benefit since most of the households raised cows.

From the total of 120 households, 90% responded "yes" for WTP for a service fee for water quality improvements of tanks. They indicated that "protecting the tank is their responsibility" as the major reason behind their WTP for water quality improvement of tanks. During the direct contingent valuation analysis, about 85.2% of respondents were willing to pay Rs.100.00 as the service charge for tank water quality improvement. The reasons behind the respondents' WTP a service fee for water quality improvement are given in Figure 1.

The results of the CL model are presented in Table 4. The coefficient of water quality attribute is positive and significant.

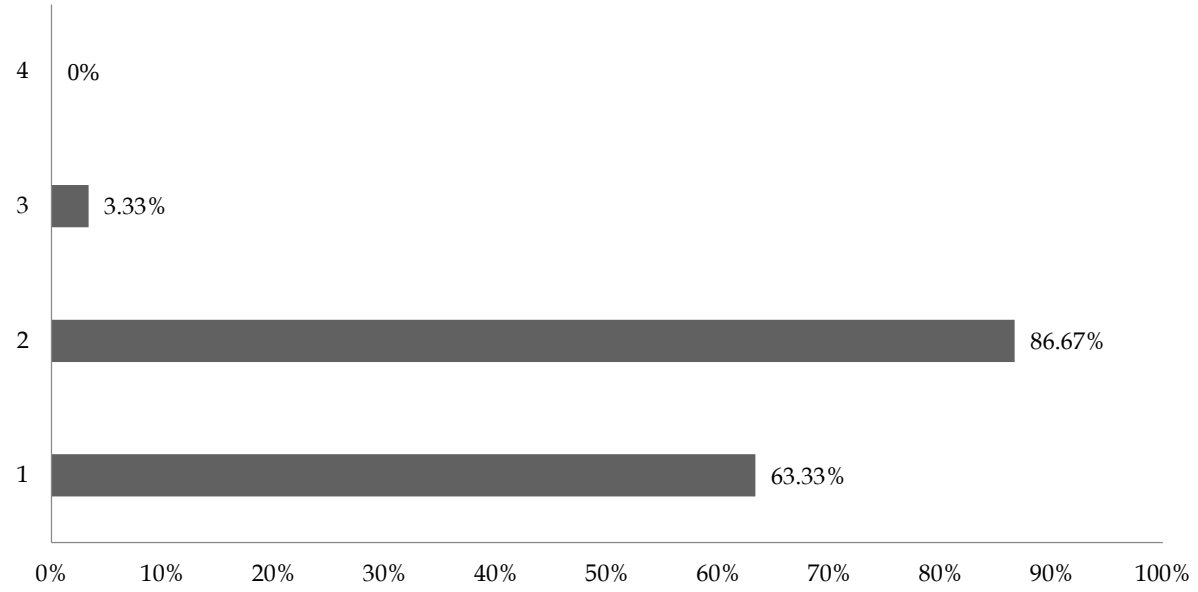

Figure 1: Reasons for Willingness-To-Pay

Note: *1: This programme is important to me, 2: I think it is our responsibility to protect the tank, 3: I want to contribute to a good cause, 4: Other reasons*

Table 4: Results of the Choice Experiment

Effect	Coefficient	SE	P-value	MWTP
Water quality				
Reduce invasive plants	0.600	0.275	0.029	60
Increase clarity transparency	1.713	0.243	0.000	171.3
Fertilizer level				
25 % less	0.799	0.186	0.000	79.9
50% less	0.141	0.212	0.505	14.1
Payment	0.003	0.005	0.544	3
Fine	-0.010	0.025	0.990	

Note: P-value for model: 0.000, SE: Standard error, MWTP: Marginal Willingness to Pay,; log likelihood: - 2058.244

It is clear that respondent's most preferred choice, which contained the level of water quality attribute to reduce *Salvinia molesta* and other invasive aquatic plants, as they observed tank water pollution from invasive aquatic plants. So, they are willing to pay for a programme that reduces the invasive aquatic plants in the tanks to improve water to drinkable quality. The level of reducing fertilizer and chemicals usage by 25% is also, positively significant. However, reduction of fertilizer and chemicals usage by 50%, the payment attribute and fine attribute are not significant.

Marginal WTP

Marginal WTP (MWTP) for each attribute of the choice set gives the amount that respondents are willing to pay for an attribute of the water quality improvement programme. The MWTP is calculated as indicated in the Equation 3 for each attribute by dividing the coefficient estimate for each attribute with the coefficient estimate for the

payment term. The Fine attribute was taken as the price attribute as it is the direct monetary attribute. According to the calculated MWTP values, respondents are willing to pay for all the attributes of a water quality improvement programme.

$$MWTP_{attribute} = -1\ (\beta_{attribute} / \beta_{monetary\ attribute}) \quad [3]$$

Where,

β : Coefficient of relative attribute

When considering the water quality attribute, the respondents are ready to pay Rs. 60.00 to reduce invasive aquatic plants, as they wish to see a tank without pollutants. People are more likely to pay Rs. 171.30, if the water quality improvement programme increases the transparency of the tank water, because they would like to observe drinkable water quality, which goes beyond the reduction of pollutants, in tanks. The respondents are willing to pay Rs. 79.90 for the water quality improvement project that suggests a reduction of 25% of fertilizer and chemical use of farmers, along with Rs. 14.10 for the reduction of 50%, as they observe the contribution of those chemicals to tank pollution. Farmers preferred 25% of reduction compared to 50%, because applying fertilizers and pesticides are crucial when it comes to agriculture. They were willing to pay a service fee to protect the tank because of the ownership feeling and as gratefulness for the services received from the village tank.

Even if there are farmer societies, they did not do much services or practices to protect the village tanks and manage the water quality level in the village tank, even they knew that protecting the tank is a responsibility of villagers also. Therefore, this programme is a great opportunity for the villagers to do their part of the responsibility of protecting village tanks.

CONCLUSIONS

Almost all the people using small tanks in the Anuradhapura district rely on ground water sources, such as lakes, tanks and rivers. Therefore, the quality of the water resources directly affects the well-being of the people.

The results obtained from the choice experiment are in line with the responses received for the questionnaire. All the respondents who engaged with the study observed pollution of tank water, due to major pollutants like invasive aquatic plants and chemicals. Further, they were willing to pay for a programme that improves the water quality of tanks. The most important finding of the study is that the respondents are willing to pay 10% of their monthly income, which is generated from tank related activities. The findings conclude that the respondents did not much consider a payment or a fine, if the programme will improve the water quality of the tank. A clear interest was seen among the respondents to engage in multiple uses. Thus, it is important for policymakers to set up an appropriate service fee for water quality improvement and to improve the sustainability of the current tank restoration programmes in Anuradhapura District.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

HD and MU: carried out the investigation and data curation and wrote the manuscript. MU: Conceptualized, designed the research, supervised the study, performed statistical analysis and interpretation of data, PR: Coded and analysed data. All authors read and approved the manuscript.

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APPLIED BIO-SYSTEMS TECHNOLOGY

Review Article **Open Access**

Role of E-Learning for Teaching and Learning in the Higher Education Sector of Sri Lanka under Crisis Situations: A Review on the Challenges, Future Potential and Way Forward

Lahiru Udayanga[1]*, Nirma Subashini[2], Virajith Kuruppu[3], Upanith Liyanaarachchi[4] and Akila Herath[5]

Abstract

Conventionally, education has been offered in classrooms, where students can interact directly with the teachers, respecting the physical presence. Recent advancements in technology play a key role in the development and expansion of the education sector. Therefore, similar to many countries in the world, the higher education sector in Sri Lanka is also progressively attempting to incorporate more E-Learning opportunities to elevate the learning process via facilitation of Blended Learning (BL) and Distance Learning (DL) opportunities. Despite the proven benefits and efficacy of E-Learning systems, limited administrative commitment, absence of adequate instructional/training programmes, gaps in technical expertise, poor telecommunication facilities, poor attitudes of students and educators, and gaps in technology readiness act as major barriers for the inculcation of E-Learning systems in Sri Lanka. However, the recent COVID-19 pandemic situation has depicted the significance of E-Learning systems in continuing higher education. Therefore, the majority of the higher education institutes have been compelled to move towards E-Learning concepts, while facing aforesaid challenges. The provision of soft-loans to empower necessary physical resources, enhancing the basic telecommunication facilities, motivation of students and academicians, and enhancing their core competencies for E-Learning through training programmes are essential to promote E-Learning opportunities in Sri Lanka. Thus, policymakers in education sector have to consider aforementioned aspects in designing a better and a sustainable E-Learning framework for higher education setup in Sri Lanka.

Keywords: E-Learning, Challenges and Potential, Crisis Situations, Higher Education, Sri Lanka

[1]Department of Biosystems Engineering, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Gonawila, Makandura, Sri Lanka

[2]Department of Horticulture and Landscape Gardening, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Gonawila, Makandura, Sri Lanka

[3]Department of Agribusiness Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Gonawila, Makandura, Sri Lanka

[4]Department of Nano-Science Technology, Faculty of Technology,Wayamba University of Sri Lanka, Kuliyapitiya, Sri Lanka

[5]Information & Communication Technology Centre, Wayamba University of Sri Lanka, Kuliyapitiya, Sri Lanka.

* Correspondence: udayanga @wyb.ac.lk

https://orcid.org/0000-0002-5687-989X

Theories of Learning and Distance Learning

A process, which improves the performance of an individual through experience and knowledge leading to changes in knowledge, attitude, or behaviour, could be simply defined as learning [1]. According to the concepts of "New Learning", learning is an interactive process that involves five dimensions:

- Development of flexible and decontextualized proficiency rather than a reminiscence of facts and contexts specific application of skills
- Facilitating learning rather than mere transmission of information to students
- Promoting student engagement as active constructors of cognitive networks rather than receptors of information
- Enhancement of analytical and clinical skills to address different issues, rather than direct application of knowledge
- Enrichment of social environments to promote self-regulated learning from failures and experiences of other students.

Therefore, mere learning of content or information only addresses one part of the learning process, while development and practice of intellectual skills/analytical thinking, interpersonal/social skills, and soft skills, also play a key role. Therefore, learning is an interactive process, in which students play an active role in enhancing knowledge while interpreting and practicing the learned content with their experience and previous knowledge.

Distance Learning is a system or a process of providing education or any instructional arrangement, where teacher and student remain geographically dispersed. Complicated and busy lifestyles and crises have promoted distance learning in secondary and higher education in many countries. In general, distance learning is considered as a non-conventional teaching and learning approach, where a variety of tools such as web media, Learning Management Systems (LMS), interactive exercises, online seminar platforms, and discussion platforms, are utilized for teaching and learning [2].

Role of E-Learning in Blended Learning and Distance Education

The concept of Blended Learning (BL) emerged as a novel concept, which emphasizes the importance of diversifying the teaching and learning modes, through the use of technology and conventional approaches [3]. This concept encourages the use of conventional teaching and learning methods along with advancing novel technologies at appropriate levels, through a variety of techniques such as lectures, discussions, case studies, live-classrooms, physical learning etc. [4]. Therefore, BL is being considered as one of the most effective and widely accepted educational models for the next era in education [5].

The collective use of the internet, digital and multimedia technologies to facilitate and enhance the learning process in a computer-generated environment, has been defined as E-Learning [6]. Effective use of software and hardware for computer-assisted learning is recognized as computer-based E-Learning, while the use of the virtual environment and the internet is recognized as Internet-based E-Learning [7]. Due to the elevated accessibility, interactivity, and flexibility, E-Learning systems have been recognized as an effective and widely utilized tool in the BL process [7-8].

The E-Learning system developed by Murray Turoff in the 1980s, as a successor of a computer conferencing software developed by him in the 1970s, is considered as the first E-Learning system in the world [9]. This system had utilized a local area network along with a software interface known as "COSY", to facilitate communication between educators and students. With time, the University of British Columbia in Canada launched the first web-based university course in 1995. Subsequently, an interface

dedicated to online learning termed "WebCT" was introduced by Murray, which supported the delivery of pre-recorded learning materials and enhanced communication between teacher and students and among students [10]. Therefore, active involvement of students in the learning process was promoted through this platform, while enhancing team decision-making and communication skills.

At present, Internet-based E-Learning platforms such as Learning Management Systems (WebCT Vista, Blackboard and Moodle, ATUTOR, etc.) and video conferencing technologies (ZOOM and Google classrooms, etc.) remain as most popular E-Learning platforms. Interestingly, the majority of higher education institutes in developed countries have already adopted E-Learning techniques for higher education [11]. Especially, most of the barriers in distance education have been adequately addressed by E-Learning platforms, elevating the efficacy of the modern teaching and learning process.

Distance Learning and Higher Education Sector in Sri Lanka

Higher education plays a key role in the sustainable development of a country and the global knowledge economy. Distance Learning, which ensures increased opportunities and accessibility to higher education, has become a major focal point in higher educational institutes of many countries. The higher education sector in the Asian region is denoting a phenomenal growth in open and distance learning. As a consequence of these developments, Asia now has more higher education institutes that offer a variety of open and distance learning opportunities, along with a relatively higher fraction of distance learners [12].

Considering the opportunities for higher education in Sri Lanka, admission for government universities has increased only up to 18% over the past few decades. Therefore, less than 20% of the total number of qualified candidates received the opportunity of enrolling in a government university. Hence, securing a place in a higher education institute has become highly competitive, while the conventional university structure has failed to fulfill the increasing demand for higher education in Sri Lanka [13]. Yet the government of Sri Lanka intends to increase participation in higher education. Therefore, non-governmental universities and open universities remain as the most preferred alternative option for higher education for students failing to secure a place in the state universities. Under this context, distance learning plays a beneficial key role in catering to the demand, becoming a new effective alternative in Sri Lanka with an undefined enormous potential [14]. This further enables the development of a qualified workforce in Sri Lanka at a relatively low cost.

With regards to the concept of distance learning, open universities still partake in the domination of distance education. The Open University of Sri Lanka (OUSL), was established in 1980 with the aim of enhancing opportunities for higher education in Sri Lanka [15]. It is highlighted as the only state university functioning under distance learning methodologies. Currently, it caters more than 40,000 students via distance learning [16]. During the period of 2003-2009, the Sri Lankan government greatly invested in the application of ICT for distance learning ensuring more access to higher education [17].

Further, the Distance Education Modernization Project (DEMP), launched during the period of 2003-2010 under the funds received from the Asian Development Bank, aiming to popularize the use of modern technology in distance education sector of Sri Lanka. This project directly aimed to enhance opportunities for post-secondary education in Sri Lanka, while improving the overall quality of teaching and learning process through the distance education partnership

programme and capacity development of OUSL [17-18]. Subsequently, the Higher Education for Twenty-first Century (HETC) project prioritized and enhanced technology-based education at the higher education institutes in Sri Lanka [19].

These projects and the advancement of technology emphasized the necessity and significance of E-Learning approaches in distance learning within the higher education sector in Sri Lanka. This motivated majority of the higher education institutes to inculcate more E-Learning-based distance learning opportunities within their programmes. The recent COVID-19 pandemic crisis has further emphasized the necessity of a properly functioning E-learning system for both higher and secondary education sectors in Sri Lanka. Hence, almost all the state and non-government higher education institutes are taking sensible steps to adapt E-Learning methodologies to enable distance learning for their undergraduate and post-graduate programmes.

Current Trends in E-Learning at the Global and National Context

With the current trend towards student cantered learning, E-learning possess tremendous potential with continuous growth in the higher education sector [20]. Several recent studies have revealed that the Asia is denoting a leading growth rate (17.3%) in E-Learning with greater benefits in education as well as in commercial aspects [21-22]. Since the inception, E-Learning has denoted a rapid evolution in terms of technology and methods/tools [21, 23].

Unlike in the initial stages, where E-Learning was frequently used for different forms of learning through the Internet, computer-based communication, and learning, the modern E-Learning methods include a variety of platforms and methods that have co-evolved with concepts such as Blended Learning, Micro Learning, Mobile Learning, Open Education, Electronic Performance Support Systems (EPSS) and Virtual Learning, etc.

Currently many higher education institutes around the world have incorporated Learning Management Systems (LMS) for the administration, documentation, monitoring, and reporting of training programmes, classroom and online events [14]. Up to now, E-Learning has evolved through Multimedia based Learning, Technology-Enhanced Learning (TEL), Computer-Based Instruction, Computer Managed Instruction, Computer-Based Training, Computer-Assisted Instruction, Web-Based Learning, Virtual Learning Environment, M-Learning, Massive Open Online Courses (MOOC) up to Selective Open Online Courses (SOOC). The recent progression in telecommunications, wireless applications, social networking applications, web 2.0, and the Internet remain as the major reason behind this [20, 24].

The evolution of Web 1.0 into Web 2.0, which transformed the publishing web into the participatory web, resulted in a huge impact on E-Learning, which enabled users to deliver, create, share, remix, and exchange content to the Web. This is not solely considered as a technological revolution, but a social revolution as well [25-27], since this enabled the growth and development of social media or social networking such as My-Space, Facebook and Twitter. These social networking sites have enabled learners to become a part, interact with each other and construct their own knowledge. A variety of E-Learning tools such as Free Google Apps for Education (Chat, Classrooms, Goggle Notes), On-line study aids (Wikipedia, Yahoo answers and Answer U, etc.), Screen casing/Pod casing, and digital storytelling platforms have evolved at present [28].

Screen Casting, enables users to create screen casts directly from their browser, making them available online where viewers can stream them directly. Meanwhile, Pod Casting enables the online publishing of video content and distribution. In addition,

tools such as Moodle, Toolbox, Group Board, etc. are also being used by the higher education institutes in delivering online lectures, conducting online assessments, and live interactions with the students. Social media sites and social networking applications (Facebook, Twitter, WhatsApp Viber, etc.) have been recognized as the most frequently used platform for academic networking by the students in developing countries, while online learning systems such as (E-Learning Space/LMS) remain as the most used platforms E-Learning platforms [29-31]. At present, LMS/MOODLE, WhatsApp/Viber, and Zoom remain as the most popular E-Learning platforms used for distance learning in Sri Lanka.

Role of E-learning in the Learning Process under Crisis Conditions

E-learning is simply a platform and a system, which facilitates the learning process through the internet using electronic devices. Many developing countries in the past have underutilized E-Learning and set priorities on the traditional learning processes. However, recent global crisis conditions like COVID-19 have deeply threatened the traditional way of learning and education. Especially, this has been visualized in the education sector in many developing countries around the globe. The outbreak of the pandemic forced many primary, secondary, and tertiary education institutes to remain closed temporarily. Most cities have turned into phantom cities with the pandemic and this has been also common in educational institutions as well. This has greatly shaken up the education process at the global level making it more vulnerable to many consequences in the present as well as in the future. Hence, under this global crisis, the entire world was compelled to depend on E-Learning for education.

However, this has promoted learning communities to rethink on E-Learning, while depicting its lucrative side, which had been hidden for a long time. Therefore, E-Learning has been coined as a "Panacea" in the time of COVID-19 crisis. As predicted by many researchers and experts up to date, it is very ambiguous to start the normal teaching and education process sooner with the prevailing conditions. Irrespective of the type of crisis, the safety guidelines are preeminent. Simultaneously, global education is struggling to find its phase to deal with this challenging situation. Therefore, scenario planning is a much urgent need for the education system to facilitate its seamless flow in these crisis events [32].

Without a proper way of identifying the nature and roles of E-Learning, it might create an environment that would be uncomfortable for both learners and educators. Therefore, understanding the role of E-Learning is pivotal in many ways. Online pedagogy should have the characteristics of accessibility, affordability, and flexibility for its users [33]. Further, any type of learning process should reach out to both urban and rural communities equally through easy accessibility and in a blended way of delivery in order to reap the maximum benefits. Simultaneously, cost-effectiveness is another paramount criterion that should be embedded in the learning process.

Therefore, E-Learning platform is an ideal solution for aforementioned aspects as E-Learning facilitates the ability to exchange knowledge from anywhere, anytime, in any rhythm, with any means. In addition, it provides a more student-centered, innovative, and flexible learning environment for teaching and learning. E-Learning generates a synchronous learning environment for its users [34].

Synchronous learning is characterized by real-time interactions between teachers and students, along with the ability of instant feedback. Simultaneously, E-Learning also facilitates an asynchronous environment, where there are no real-time interactions [35]. More importantly, E-Learning platforms act as a relatively cheaper mode of education, since it requires a lower cost of transportation and accommodation, resulting a lower overall

cost for institution-based learning.

Another prominent role of E-Learning is its ability to facilitate a large number of students from different parts of the world at any time. Most of the tertiary/higher education institutes have fully digitalized their education systems. Especially E-Learning facilitates the multiplicity in the learning process for educators [36]. On the other hand, this encourages even to personalize or customize the education process. In addition, E-Learning creates opportunities for multi-stakeholders to involve in the education process by widening its reach without limitations. Both learners and educators are able to opt for preferable time slots with their busy schedules. Also, E-Learning enhances the efficacy of knowledge [37]. Even if there is a scarcity of educators during a crisis event, E-Learning could still facilitate learning communities to achieve their objectives without discontinuing the process.

Objectives of the learning process could be accomplished in the shortest time and hence, the impact of E-Learning is vast. Even though some believe that E-Learning does not facilitate communication between the educator and the learner, if used effectively it helps to overcome challenges that may hinder active participation of students, including the fear of talking in front of other learners. Therefore, E-Learning could be used wisely to motivate students to interact with others, to exchange and respect different points of view.

In overall, E-Learning defies the typical constraints of distance, cost, and wasting of time. Hence, E-Learning is the best alternative currently available for distance learning. E-learning applications and concepts are not limited to a certain level of education or discipline and thus provide universal assistance for all levels of education. The option of enabling self-learning or independent learning breeds an empowered student community [38]. Especially receivers could engage in the learning process according to their own phase rather than following a command of chain in a typical classroom environment. Diversity is one of the biggest advantages of E-Learning. This delivers many opportunities to different learning communities at any given time. Currently, the entire globe is witnessing the implementation of E-Learning. Therefore, it's time for experts to re-think education strategies and work on improving E-Learning for the betterment of many. In the crisis condition, E-Learning has become a must and a valuable concept. In another word, E-Learning is one size that fits all.

Role of ICT on Adoption and Promotion of E-Learning in Sri Lanka

Practically all aspects of modern life have been influenced with the improvement of ICT and its allied branches. ICT has given accessibility to much more rich information in all spheres, including the education sector. Importantly, education is one of the prominent sectors in Sri Lanka, which has adopted number of novel technologies recently, in order to enhance its overall efficiency and effectiveness. Adopting ICT appliances are vital in the promotion of E-Learning due to its enhanced capability of offering a high-quality learning experience to both educators and learners [39].

A successful E-Learning platform depends on both technology and its infrastructure setup. However, most Sri Lankan education institutes are still in the primary stage with respect to both ICT technology and its infrastructure. Simultaneously, it is important to understand that, the E-Learning Systems (ELS) are now playing a key role beyond teaching since it enables access to learning resources without any limitations in time or location. Hence, learning systems have undergone a rapid transformation recently promising much more deliverables, in terms of both tangible and intangible outputs [40]. Since the internet has been widely used by many users, the promotion of E-Learning should be initiated

through the internet and internet-based distance education is considered to be the greatest common E-Learning technological implementation of ICT.

Implementation and maintenance of a sound E-Learning system is not a simple task and it requires a strong Management Information System (MIS). Therefore, MIS is the foundation of an E-Learning system. Video conferencing, interactive discussions, accessibility to sessions, and the possibility of reviewing already stored and recorded content are important features of many E-Learning systems. However, it is recommended to have a solid Learning Management System (LMS) to up and run such activities. Many higher education institutes in Sri Lanka are struggling to fulfil this requirement and to maintain static websites, where only single or few features are available. This vastly limits the capacity and capabilities of E-Learning platforms making it tedious among the learning community [41]. ICT-based learning systems are currently becoming more and more popular while assuring quality requirements. The use of ICT in E-Learning could immensely improve social, vocational, catalytic, and pedagogical aspects [42]. Hence, the innovativeness could be easily embedded within the E-Learning systems through ICT.

Challenges Faced in Promoting E-Learning within Sri Lanka and Strategies to Cope

Satisfaction on E-Learning could be greatly influenced by a variety of factors including social characteristics, technological readiness of students and teachers, institutional policies and government or institutional commitment etc. [43-44]. Among social characteristics, age, previous knowledge on ICT, attitudes toward new technologies and learning/teaching style of students and educators may exert a powerful influence on the acceptance of E-Learning [31, 45]. Numerous studies have emphasized that the degree of ICT knowledge of both students and educators, is significantly influencing the acceptance of E-Learning approaches [46-47], while few studies have opposed this claim [48].

The technology readiness of the students and teachers/lecturers also play a key role in acceptance and satisfaction on E-Learning [49]. Under this, the degree of familiarity with E-Learning systems and ICT, availability of physical hardware (computers, laptops, tablets or mobile phones, etc.), and accessibility to the internet could influence the use of E-Learning among student and teacher community. Especially, the limitations in the internet facilities (poor bundle width, cost of the connection, issues in coverage, and connectivity) has been recognized a major barrier in promoting E-Learning in Sri Lanka [44]. Therefore, the government of Sri Lanka must focus on empowering the rural communities with adequate physical infrastructure facilities related to telecommunications through appropriate funding and policy interventions. Several recent studies have revealed that smartphones are being used as the most commonly preferred device for E-Learning [50-51]. In addition, soft-loan schemes could be used to support the poor income families to purchase required physical devices for E-Learning. At present, the undergraduates in Sri Lanka are provided with soft-loan schemes to purchase laptops to facilitate their learning process.

Understanding the role of ICT is important to address such issues. ICT for E-Learning is not simply about use of high-tech equipment or applications. The main role of the ICT should be the creation of an enabling environment for E-Learning platform for its intended function [49]. ICT should enable E-Learning through generating required functions such as gathering, distributing, and communicating information through computers and computer-based networks. Facilitators should be also there within the system, in order to operate and coordinate the entire procedure. Combination of both of these aspects promotes E-Learning within the learning community. This should also be

aligned with the national policy frameworks as well. Policies are the foundation to implement such processes and without policies, ground-level implementation is not realistic. Intuitional support is also required to monitor and evaluate the procedures time to time.

Another main challenge for E-Learning in Sri Lanka is poor delivery of the intended output to the student community. Even though E-Learning is becoming a popular concept in the country, degree of E-Learning utilization among primary, secondary and tertiary education categories remains not equal and lack of adequate ICT appliances is one major reason behind this. In addition, the academic discipline, for which E-Learning is used, and the academic year of the students could also influence the acceptability of E-Learning. The limited diversity in E-Learning methodologies used in Sri Lanka could be recognized as the key reason behind the aforementioned issues. Enabling a mixed learning environment with more attractive and efficient E-Learning practices is essential. The development of ICT on the other hand inspires E-Learning and its environment. Therefore, ICT and E-Learning are like two sides of the same coin.

Current performance of E-Learning systems could be greatly enhanced through identifying possible weaknesses in the prevailing ICT facilities. Therefore, the support of ICT is important to enhance the E-Learning diversity in Sri Lanka. A variety of teaching approaches (lectures, interactive sessions, quizzes, interactive learning exercises, video tutorials, etc.) and attractive web-based learning models could be incorporated into E-Learning systems to ensure the provision of a BL experience to the undergraduates [5].

Regardless of the proven efficacy of E-Learning for distance education, such E-Learning systems should be designed carefully with attention on emotional and social requirements of students and teachers/lecturers [52]. The learning community should be able to feel the realness of the learning process within the created virtual environment to achieve the intended objectives of the system. For this, the degree of self-motivation, self-management, self-control, and time management of educators and students should be considered ad well respected [53]. Thus, the right mix of technology, infrastructure with the right mix of expertise may aid to develop a proper E-Learning platform in the country. Therefore, the role of ICT is of utmost importance to adopt and promote E-Learning. The online environment must permit different technical platforms, organizational models, and pedagogical beliefs [54].

Another study conducted by Andersson [55] has recognized poor attitudes of teachers/facilitators, nature of teaching and learning activities, limited accessibility and flexibility, poor student support, attitudes and academic confidence as key barriers for inculcating E-Learning in Sri Lanka. Building up positive attitudes among students and educators towards E-Learning through awareness programmes and empowering them with necessary core-skills and physical resources is important to overcome such issues [56].

Further, motivating few groups to use E-Learning systems effectively in their teaching and learning process, may lead them to act as catalysts persuading their peers to adopt E-Learning [57]. Therefore, conducting proper training programmes and awareness sessions on E-Learning techniques is essential in Sri Lanka. For this, the active involvement of higher education institutes and the government is vital. In addition, the provision of such training sessions would encourage the educators to use diverse E-Learning tools in the teaching process, capturing the attention of the students. In addition, this would enhance the active involvement of the students.

Several other studies have revealed a

level of hesitancy among academicians to support E-Learning platforms, limited administrative support, higher workloads, and limitations in available physical resources, as barriers for promotion of E-Learning [58-59]. Therefore, the administration of the higher education institutes should monitor the progress of the E-Learning systems and they have to play an active role in the process. Empowerment of the students and educators with basic physical resources, provision of administrative support and enhancement of core competencies required for effective use of E-Learning tools are such vital roles expected. The government of Sri Lanka can also support such activities through policy level interventions, which will be beneficial for the country, especially during a crisis condition like COVID.

Recommendations & Way Forward

Despite the perceived benefits of conventional physical teaching and learning practices, the advancement of technology and evolution of sophisticated human lifestyles, requires for more flexible, accessible education tools. E-Learning provides an ideal solution for above requirements, with its unique flexibility, low-cost, higher accessibility and ability of providing a Blended Student-Centered Learning experience. At present, many countries of the world are increasingly inculcating E-Learning methods for secondary and higher education. Meanwhile, the higher education sector of Sri Lanka is also progressively attempting to adopt E-Learning into the teaching and learning process. Especially, the role played by E-Learning platforms during COVID-19 pandemic situation for continuation of education processes in the country is remarkable.

However, numerous barriers such as poor administrative commitment, gaps in technical expertise and telecommunication facilities, poor attitudes of students and educators, and lower degree of technology readiness, have restricted the efficacy and popularization of E-Learning systems in Sri Lanka. The provision of soft-loans to empower necessary physical resources, enhancing the basic telecommunication facilities, motivation of students and academicians, and enhancing their core competencies for E-Learning through training programmes are essential to promote E-Learning opportunities in Sri Lanka. For this, policymakers in the education sector should consider aforementioned aspects in designing an ideal and variable E-Learning framework for the higher education sector in Sri Lanka.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

LU: Conceptualized the study and wrote the manuscript. NS: Wrote the manuscript. VK: Wrote the manuscript. UL and AH: Reviewed the manuscript. All authors read and approved the manuscript.

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