QoL Modeling in the Agricultural Supply Chain

Subjects: Agricultural Engineering

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The agricultural supply chain (ASC) in the hinterland refers to the entire post-harvest process of processing and distributing agricultural products in rural or secluded areas to be brought to big city markets. This scheme involves various stakeholders (farmers, trading centers, consumers), processes (logistics, storage, monitoring), and infrastructure (traffic and road systems, negative environmental emissions) to ensure the efficient flow of agricultural products from farms to consumers. The quality of life (QoL) in the hinterland can improve with the introduction of disruptive technologies, but no comprehensive studies have explored the QoL of individuals involved in the ASC–socioeconomic system of hinterland communities.

Keywords: agricultural supply chain ; disruptive technology ; hinterland ; life quality index ; quality of life ; sustainability

1. Overview of Quality of Life and Its Mathematics

The concept of quality of life (QoL) is multifaceted and encompasses diverse domains, encompassing physical, psychological, social, family, and environmental dimensions based on the standard World Health Organization's Quality of Life Model [1]. Through evaluating these domains, it becomes possible to discern the impact of technologies deployed in the agricultural supply chain on individuals' overall well-being, especially that of its stakeholders. In [2], QoL was evaluated to design better transit-oriented developments for people living near station areas. The authors created a model of a QoL index (1) that examines how various quality indicators impact bid rent. Through models (2) and (3), an individual's perceived quality of life is quantified in terms of their willingness to pay rent. In other words, it represents the additional amount individuals are willing to spend on rent to attain a higher quality of life.

$$, = \sum \quad , \cdot (\quad , - \_\_ ,) \tag{1}$$

$$', = \frac{\quad ,}{,} \tag{2}$$

$$, = \quad ', \cdot \quad + \_\_ \tag{3}$$

where $QoLs,i$, is the QoL index without unit standardization of residential location i for socioeconomic group s; Xi,l is the level of quality indicator l of location i; Xs,l is the average level of quality indicator l for group s; $\beta s,l$ is the value parameter of quality indication l for group s; $QoL's,i$ is the QoL index with the unit of willingness to pay a rent premium for location i for group s; $\beta s,rent$ is the value parameter of rent cost for group s; and BRs is the average rent paid by socioeconomic group s [2]. In addition to the aforementioned study, [3] also constructed a model to examine the mutual relationship between the Mumbai-Ahmedabad high-speed rail (MAHSR) and its impact on India's overall GDP and the quality of life experienced by individual citizens. To assess the improvements in citizens' quality of life, the researchers employed the QoL accessibility method based on inter-industrial inputs from the industry, as shown in (4) and (5).

$$= \quad \times \quad \times \tag{4}$$

$$= \sum \sum \tag{5}$$

wherein $DINpqij$ is the demand for inter-industrial input from industry *p* in zone *i* to industry *q* in the surrounding zone *j*; Aqp is the input coefficient from industry *q* to industry *p*; $PROpi$ is the production value of industry *p* in zone *i*; and $PTqij$ is the probability of each industry in zone *i* trading with industry *q* in zone *j* [3].

The presented QoL models provide a framework for evaluating the different dimensions that contribute to a person's quality of life, whether it is based on a socioeconomic or industrial aspect. QoL quantifies an individual's or a group's well-being and allows assessment of how different innovations can impact relevant stakeholders. Therefore, a QoL model can contribute to long-term sustainability by incorporating environmental, social, economic, and psychological considerations. By accounting for the interrelationships between these domains, it helps guide decision-making or developing technologies toward approaches that promote sustainable development.

The need for having QoL models becomes evident when considering the impact of technological advancements on the agricultural supply chain, which addresses food insecurity and fosters economic growth. While these innovations bring substantial benefits, it is crucial to recognize the significance of QoL factors for all stakeholders involved in their design and implementation. A bibliometric analysis was conducted that revealed that QoL assessments were predominantly prevalent in the domains of medicine and health-related fields, whereas their presence in other sectors was limited. Although some studies used the keyword "environment" in their QoL assessments, its connection with "quality of life" or "well-being" was extensively limited [4]. There are several shortcomings in focusing on an individual's QoL, especially in rural areas, as studied in [5]. This highlights the need to incorporate QoL considerations, especially in the hinterland agricultural sector. Technological interventions should be practical, user-friendly, and valuable to ensure an improved quality of life for the end users [6]. Furthermore, when stakeholders perceive that their concerns and perspectives are acknowledged, they are more inclined to embrace and adopt the technologies, facilitating successful implementation and yielding positive outcomes [7].

By incorporating QoL considerations, disruptive technologies can effectively prioritize the needs and well-being of all stakeholders. In the context of the hinterland agricultural supply chain, the integration of QoL factors in the implementation of technological interventions enables inclusive development for farmers, their communities, and end consumers. This holistic approach ensures that technological solutions are developed with a human-centered perspective, culminating in more pertinent, efficacious, and sustainable outcomes [6]. For farmers, disruptive technologies that conscientiously address their QoL requirements, such as by assisting them in acquiring knowledge and aiding in decision-making, have the potential to boost the profitability of agriculture and contribute to its economic, environmental, and social sustainability, leading to income stability and an overall improvement in well-being [8]. Farmers are also better positioned to optimize the benefits derived from technology when these advancements are tailored specifically to their needs [9]. The improved well-being and satisfaction of farmers and workers through QoL considerations translate into increased productivity, enhanced job satisfaction, and better work–life balance, which, in turn, leads to the sustainability of the agricultural sector, stability, and growth within the farming industry [10]. Innovators and future research endeavors can also capture the holistic nature of farmers' well-being and provide valuable insights for enhancing their overall QoL through incorporating the aspect of quality of life, particularly eudaimonic well-being [11]. In effect, the integration of QoL considerations ensures the long-term sustainability of agricultural practices and the entire agricultural supply chain, benefitting all stakeholders, including farmers, workers, and the hinterland community, both in the present and future generations.

2. Quality of Life Modeling in the Agricultural Supply Chain

A simple supply chain typically begins with the procurement of raw materials and continues until a final product reaches the consumers [12]. The agricultural supply chain, on the other hand, is more complex than other supply chains in terms of product perishability, seasonal supply–demand fluctuations, and consumer awareness [12]. In the agricultural supply chain, the pre-harvest phase pertains to raw materials procurement through production, whereas the post-harvest stage includes storage, distribution, and retail. Operations involved in the process from pre-harvest to post-harvest have been integrated with technology due to the rapidly increasing demand for food and competition for resources. However, many challenges regarding post-harvest operations still need to be addressed, such as the lack of product traceability and information balance [12].

QoL is the perception of a person of their overall comfortability and stability in everyday life; hence, the quality of their life. Based on [13], the standard of QoL varies from culture to culture and social position; thus, different models are present to cater to the different statuses of people. When determining the QoL of a region, it is important to consider its multidimensional nature. There can be an objective or subjective assessment of QoL, depending on the purpose of the assessment. QoL indicators include accessibility to housing, education, food, leisure and transport, and the quality of subjects' health, their environment, and the economy.

Urban and rural areas offer different means of measurement for QoL, mainly due to their differences in population size. Population size, however, is not the only major factor that differentiates the two, but also their population density and the cultural diversities within the community, as discussed in [14]. With a larger population, more opportunities for businesses and access to connections are available, typically enabling a better potential improvement in QoL determinants such as leisure, food, and economy. This is the reason capital cities in general are the more densely populated regions; they promote better opportunities for jobs and businesses. It was also highlighted that cultural diversity is also a crucial factor because it implies different needs in a region [14]. A greater amount of needs typically is a challenge to increasing QoL, because more effort needs to be made to satisfy these needs. In contrast, rural areas typically have lower population density, limiting access to certain services but also incurring fewer needs to be satisfied.

The various modeling approaches involving QoL, and its matched applications, are summarized in **Table 1**. Subjective well-being (SWB) measures the rate of satisfaction and fulfillment of individuals. Composite Indices (CI) measure the Human Development Index (HDI) and Gross National Happiness (GNH) index. Multi-Criteria Decision Analysis (MCDA) is a collective technique consisting of an Analytic Hierarchy Process (AHP) or Multi-Attribute Utility Theory (MAUT), which are survey-based approaches that employ pairwise comparisons. The Capability Approach (CA), on the other hand, focuses on the priorities of an individual with respect to their capabilities to achieve certain goals. The Participatory Approach (PA) involves workshops, focus groups, and community consultations. Data-driven approaches (DA) use higher statistics and machine learning algorithms. Note that each QoL modeling technique has its own advantages, limitations, and applicability.

Table 1. Summary of QoL model applications and the techniques involved.

Technique	HC	AG	SWCD	UPE	ED	PPG	AP	ASC	QoL Applications
Subjective well-being	✔	✔	✔	✔		✔	✔		[14][15][16][17][18]
Composite Indices	✔				✔				[19][20]
Multi-Criteria Decision Analysis	✔	✔		✔	✔		✔	✔	[21][22][23][24][25]
Capability Approach		✔	✔	✔	✔			✔	[26][27][28][29][30]
Participatory Approach	✔	✔	✔	✔					[31][32][33][34]
Data-driven approaches	✔	✔		✔					[35][36][37]

HC—healthcare, AG—aging and gerontology, SWCD—social work and community development, UPE—urban planning, transportation, and environment, ED—economic development, PPG—public policy and governance, AP—agricultural production, ASC—agricultural supply chain.

QoL assessment models used in the agricultural field are based on existing QoL models (**Table 2**), modified to be more appropriate in focusing on the lives of those involved, such as farmers. QoL assessment techniques that have been used before are summarized in **Table 2**.

Table 2. Comparison of existing studies on QoL assessment in agricultural supply chain.

Existing QoL Assessment Methods in Agricultural Supply Chain	Description	Results	Reference
McGill QoL Questionnaire, Independent Living and Working (ILW) Level, demographic analysis	**17-item McGill QoL survey that includes questions about the respondents' overall physical, psychological, and existential well-being, physical symptoms; support levels on a scale of 0–10.**	**The United States Department of Agriculture (USDA)'s AgrAbility project resulted in a significant statistical and practical improvement in the QoL and ILW of the respondents. It was most effective on people with higher ILW scores, but also had a significant positive impact on people with disabilities.**	[38]

Existing QoL Assessment Methods in Agricultural Supply Chain	Description	Results	Reference
Descriptive statistical analysis in relation to QoL Structural Equation Modeling (SEM), Structural Model of Social Capital and QoL of Farmers in Supporting Sustainable Agriculture	The QoL survey used a rating of 1–5 in terms of satisfaction with these sub-variables: community well-being, emotional well-being, health, and safety. To satisfy the model, the respondents' social capital was considered the dependent variable, while their QoL was the independent variable.	Results of surveys in Sedayulawas Village, Lamongan Regency, Indonesia, indicate that the respondents consistently have a good quality of life with regard to the agricultural aspect. All indicators of QoL were met with a slightly positive attitude from the respondents, who had a mean QoL score of 3.5604.	[39]
WHOQOL (World Health Organization QoL)-based assessment	The QoL of the respondents were classified into four domains, namely, physical, psychological, social relations, and environmental quality and material well-being.	The implementation of multipurpose and multifunctional landscapes in urban communities, as opposed to those with purely economic purposes, promoted a better self-image and a practical increase in the QoL of its residents, as reflected in the gated communities of the Greater Cairo Region, Egypt.	[40]

The three existing QoL assessment methods mentioned (**Table 2**) were similarly based on farmers' physical and psychological well-being, social relations, and economic and environmental impacts. These bases were formed in the context of farmers living their regular day-to-day lives, with the exception of the first assessment. The assessment of their QoL was not based on the improvement of their lives by emerging technologies.

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