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Can Trail Bridges Promote Both Environmental Aesthetic Value And The Economic Development In Rural Areas?: Evidence In Northern Province Of Rwanda

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Abstract

In this study we analysed the influence of the trail bridges on the aesthetic value of the environment, and on the economic development of the rural areas alongside with the functionality of trail bridges in northern province of Rwanda. The beneficiaries of the trail bridge and the local leaders were sampled randomly (local bridges beneficiaries) and purposively (local leaders). 12500 households and local leaders were our target population from whom 267 households' representatives and 11leaders were used as sample. It was found that Gakenke and Rulindo districts are the districts that has the most trail bridges built so far, totalling 75% of all the bridges built in the Northern province. There is a significant increase in building trail bridges with years; 65% of the total trail bridges were built in only two years (2021 and 2022).

Regression Statistics indicated that trail bridges shortened travel time and speeded economic activities by boosting jobs. The value of R square (0.62806) proves that the change in new economic activities is driven by the travel time and the correlation is strong, as shown by the value of Multiple R=0.79. This means that the longer the travel time, the less the possibility of new economic activities.

In addition, shortened travel time boosted new job and this is shown by the value of R square (0.654), and the value of Multiple R=0.808 proving a strong correlation.
The promotion of trail bridges in hilly countries with deep valley could accelerate sustainable socio economic development.

Key words: Trail bridge; Environmental aesthetic value; Rural areas, Environmental aesthetics, and Economic development.

1. Introduction

Aesthetic value of environment is one of the values philosophically attributed to the nature by environmental ethicists (Brady & Prior, 2020). It is a form of intrinsic or non-instrumental value, where something is not valued as a means to some end, rather it is found to have value in and for itself (Brady & Prior, 2020). Aesthetics was defined as a 'science of sensory cognition' by Alexander Baumgarten

(Brady & Prior, 2020). It is based in the admiration felt vis-à-vis the perceptual qualities of an object.

The land scape is valued by its aesthetics, and the latter has a role to play in enhancing the visitation of a place, (Othman, Mohamed, & Ariffin, 2015). The aesthetic quality of water resources is valuable to the community as it enhances the recreation services of lakes and rivers such as fishing, picnicking and swimming (Corrigan, Downing, & Egan, 2007).

The Aesthetic Value of pedestrian bridges is measured in the extent of the homogeneity and integration of the bridge with the surrounding scene, (Ismael, Mohson, & shalal, 2021). Though a bridge is not a destination, people have been finding innovative ways to build sturdy spans that add aesthetic value and enhance the beauty of a landscape, (Romano, 2019)

Economic development is the creation of wealth in which the community benefits are created. It is an investment in growing your economy and enhancing the prosperity and quality of life for all residents. (California Association for Local Economic Development). In Rwanda 72.1% of the resident population (9,545,149 inhabitants) live in rural areas, 83% of the households in the rural areas are agricultural households ((NISR), 2023), but they also depend on multiple sources of income, and they move to distant places to build their livelihood. (Cottyn & Nijenhuis, 2021). In their trail handbook, the California Department of Parks and Recreation defines a trail bridge as a structure along a trail that spans over a waterway, precipitous slope, or other unstable ground that cannot support trail construction (California State Parks, 2019). Trail bridge also means a permanent physical structure built to cross a river, stream or ravine lying on a trail; this includes steel cable bridge and steel truss bridge (Nepal, 2006). Considering the span of a bridge, there are 2 types of bridges: Short span bridges (up to 120m span) and long span bridges (beyond 120m). In terms of bridge types, there are three types of bridges: truss bridge, suspended (D-type) and suspension (N-type) (Sapkota, 2017). For the sustainability of a bridge, the operation and maintenance plan are paramount (Budha & Joshi, 2022). The cost of maintaining and repairing a bridge is far less than the cost of replacing it when it has failed because of neglect (Groenier & Scott, 2020).

The topography of Rwanda is rough with steep hills and deep valleys, and there is a challenge of uncertainty in access during flooding (Thomas, et al., 2021) , as Rwanda has 861 rivers (REMA, 2021) and almost 80% of the water crossings in Rwanda are local timber bridges that are often washed away when a river is flooded (Shirley, Noriega, Levin, & Barstow, 2021).

Different researchers (Starkey & Hine, 2014), (Salami, Kamara, & Brixiova, 2010), (Pande, 2017) proved that rural isolation, lack of access and lack of transport infrastructures are the main reason of the rural poverty, and some researchers have suggested trail bridges to be one of the solutions to the rural isolation (Brooks & Donovan, 2020), (Evans, 2021) (Munyaneza & Mberahayo, 2021).

In the recent study evaluating the potential community benefits of rural trail bridges in Rwanda, they researchers didn't find an impact attributable to the trail bridges other than the increase in the labor market income due to small sample size and short duration (Thomas, et al., 2021). Even though they are a key connectivity network, trail bridges, when poorly designed, they become unsafe and may be washed away by the flooding river, losing their functionality and putting people at risk (Macharia, et al., 2022).

In Rwanda, when it comes to trail bridges, researchers have talked about the impact of trail bridge but none of them tackled the functionality of the bridges behind that impact. In addition to that no research was found about the environmental values of trail bridges.

Therefore, in this research, the role of trail bridges in promoting both the environmental

aesthetic value and the economic development in Northern province of Rwanda was assessed. In addition, four aspects of the economic contribution of trail bridges were assessed, altogether with the functionality of the latter.

2. Methodology

2.1. Description of the Study Area

This research was conducted in the Northern province of Rwanda, in 5 districts; Rulindo, Gakenke, Gicumbi, Burera and Musanze. This province has 89 sectors, 414 cells and 2740 villages. The trail bridges that was assessed in this study have been in use for at least one year; it means bridges that have been completed before the end of 2021.

2.2. Research design

This research is a descriptive research (Sandra L. Siedlecki, 2020). It used a mixed method approach combining quantitative and qualitative methods. The methods that were used in data collection are surveys and observation.

The sample size was drawn referred to the slovin's formula (Wulandar & Kurniasih, 2019):

$$n = \frac{N}{(N.e^2 + 1)}$$

Where: n = Sample size, N = Population size, and e = Acceptable sampling error

In this research we considered a margin error of 6% and a confidence interval of 95%.

Taking into account the number of population and households served by trail bridges, this research targeted 12500 households and local leaders. Herein, 267households representatives and 11leaders were used as sample.

Table 1. Shows the sample size form the targeted population

DISTRICT	CATEGORY OF TARGET POPULATION	POPULATION SIZE	SAMPLE SIZE	TOTAL SAMPLE
GAKENKE	Household representative	8750	187	
	Local government (executive secretaries)	4	4	
	A District representative	1	1	
RULINDO	Household representative	2500	53	**278**
	Local government (executive secretaries)	2	2	
	A District representative	2	2	
GICUMBI	Household representative	1250	27	
	Local government (executive secretaries)	1	1	
	A District Representative	1	1	

The primary data sources in this research were the household representatives and beneficiaries of the trail bridges, and the leaders at the sector and the district levels. The secondary data sources were the reports from the districts and the trail bridge builders that partner with the districts in building trail bridges

The coordinates of the bridges were collected using a Global Positioning System (GPS) device.

Survey was one of the techniques used to collect data during this research. It was performed using mainly semi structured interviews and questionnaires that were tailored by the researcher in order to collect data. The selected participants completed the questionnaire made of semi structured questions. The researcher provided any support needed the respondents to allow them to give accurate information while responding on the questionnaire.

Observation was another technique used during this research. The site observation was made on bridges, to get visible information. Here we mean qualitative observation

involving sight. The documentary technique helped the researcher to exploit written documents under the study.

The geographic coordinates of the bridge's location captured using GPS were processed using ArcGIS10.8

SPSS(Statistical Package for the Social Sciences) was used for the analysis of the data collected using a questionnaire.

The quotes from the interviews were transcribed and used to add more clarification on the graphs and tables.

3. Results and Analysis

3.1. Profiles of respondents

The respondents who participated in this research were farmers (76%), Businessmen (4.9%), those combining both Farming and Business (13.1%), and others (6%) including civil servants, staff from private institutions, and others (Table 2* in Supporting document).

Table 2. Respondents from government and bridge builders

Description	Frequency	Comments
Local government representative	7	Executive secretaries of Sectors
District level	4	District Engineers and others

The Table 2 above show the respondents other than the households' representatives. Local government representatives; mainly executive secretaries of sectors at sector level, and district engineers and staff in charge of one stop center, at district level, were other respondents in this research.

3.2. Trail bridges enhancing the Environmental aesthetic value

The trail bridges accommodate not only people of all ages, but also the livestock, motorcycle and bicycles. In some areas, the respondents confirmed that before the construction of the trail bridges, people and the livestock used to pass through the water to go to the other side of the river. This may affect the turbidity of water, and thus its aesthetic quality. The trail bridge, as a crossing structure, allow people and livestock to cross without disturbing the river, and in that way contribute to the aesthetic quality of water. By contributing to the aesthetic quality of the river, the river-trail bridges play an indirect role in enhancing the recreation value of that river such as fishing, swimming and picnicking as Corrigan and co-writers elaborated (Corrigan, Downing, & Egan, 2007).

However, on some rivers that are always turbid like Base river where trail bridges such as Kwiterambere, Taba, Rutenderi and Gitwa are built, the contribution of the trail bridges to the aesthetic quality of the river could not be perceivable easily, but rather the aesthetic of the landscape. Many respondents in Gakenke district who live near Ntaruka trail bridge affirmed that people from many places when they pass near that bridge, they get out of their cars and come to take pictures on the bridge. This confirm what has reported in (Romano, 2019), that, even though a bridge is not a destination it can be built in a way that add an aesthetic value to the landscape, and a beautiful landscape is enhanced when you are standing on a beautiful bridge.

The aesthetic of the trail bridge; this means the design of the bridge and the state of the bridge, seem to have a huge role to play on the aesthetic contribution of a bridge to the landscape. However, the respondents confirmed that old/ damaged trail bridges, such as Shagasha, seem not contributing to the aesthetic quality of the landscape.

Figure 1. A picture of a trail bridge in Gakenke district, source: Author

Beside the environmental aesthetic value, interviewed respondents pointed out other values brought by the trail bridge to the environment. One interviewee who uses theKabutimbo trail bridge said "Before the trail bridge, the existing crossing used to be washed away when the river was flooding. This led to regular cuts of big trees to replace it, which was not environmentally sustainable. The trail bridge mitigated the regular cut of trees and injuries or deaths related to the transport of those trees to replace the ones washed away crossing every rain season."

3.3. Assessment of the contribution of the trail bridges on economic development in rural areas

- Access to the market and food security

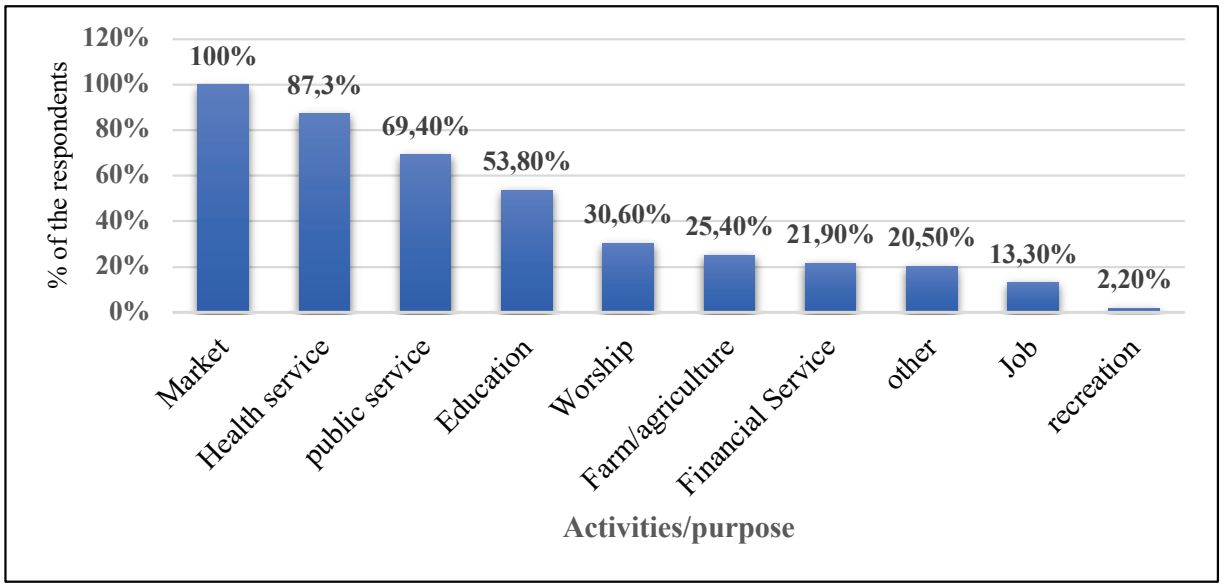

Figure 2. Views on the trail bridges use for the travel purpose

Figure 2 indicates that the respondents use the trail bridges to access the market, jobs, schools, places of worship, and other essential services such as heath, public, and financial services. Some respondents interviewed declared that the trail bridges have facilitated the teachers and the students to reach their respective schools in a reasonable time. Other reasons for travel that were stated by the respondents include funeral services, visiting friends and families. These reasons show the role of the trail bridges in connecting the users especially for important social events. All respondents declared that they reach the market by crossing the trail bridges ranking this travel purpose as the first.

From the Table 1 it is clear that the majority of the population lives of the agriculture, this fact is confirmed by other studies showing that 82% of the population in Gakenke district (Nzamwita, 2019), 80% in Gicumbi district (Ndayambaje, 2017). The main cash crops produced are coffee and pineapple in

Gakenke (Nzamwita, 2019); tea, coffee and horticulture for Gicumbi (Ndayambaje, 2017); Coffee, tea, Wheat, Maize and Horticulture for Rulindo district (KAYIRANGA, 2017). Hence people need to access markets to sell and buy different products. This is proved by all respondents that use the trail bridge to access the market as shown by the Figure2. All those three districts have village markets, mini markets and modern markets (KAYIRANGA, 2017) (Ndayambaje, 2017) (Nzamwita, 2019).

In addition to that, dairy farming is relatively important and people cross the bridges to reach the milk collection centers.

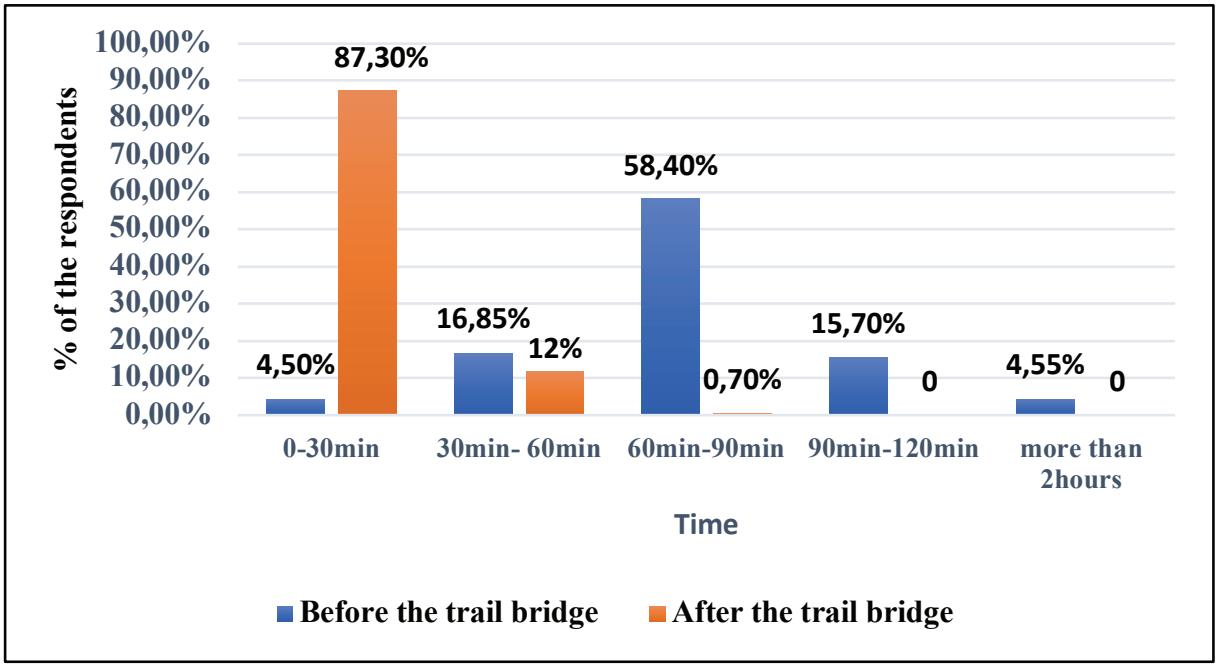

Figure 3. Travel time

Figure 3 shows that the respondents (58.4%) predominantly had to travel 60-90 minutes, during the river overflow before reaching the market while currently 87.3% of the respondents declared they use less than 30 minutes to access the same services after the trail bridge. 0.7% of the respondents still use more than an hour to travel to the market during the river overflow. An interviewee from Gaseke said that *"during the river flooding we used an alternative way to go to the market, and it was time or money consuming as we walked more than an hour or take a moto of 700FRW (Rwandan Francs). Now that there is a trail bridge we use less than 20 minutes for the same trip"*.

Commenting on the importance of the trail bridge, a respondent in Rusasa sector who use Kabutimbo trail bridge said "*Before it was difficult to take goods to the market, we then ended up selling them at a lower price"*. He Further declared that also those who tried to bring their products to the market would fall in water.

The Figure 4 shows that the problem of food security has been solved after the arrival of the trail bridge, as it was affirmed by most of the respondents. Three facets of the food security are food availability, food access, and food use (Nzabuheraheza & Nyiramugwera, 2017). Discussing about the food availability and food access, the trail bridge granted an all-season safe crossing to people allowing them to reach their farm across the river, as shown by the Figure 2, 25.4% of the respondents the bridge to access their fam. Thus, crop is harvested on time, consumed or/and made available at the market. Trail bridge facilitate the access to the market, thus, to the available food.

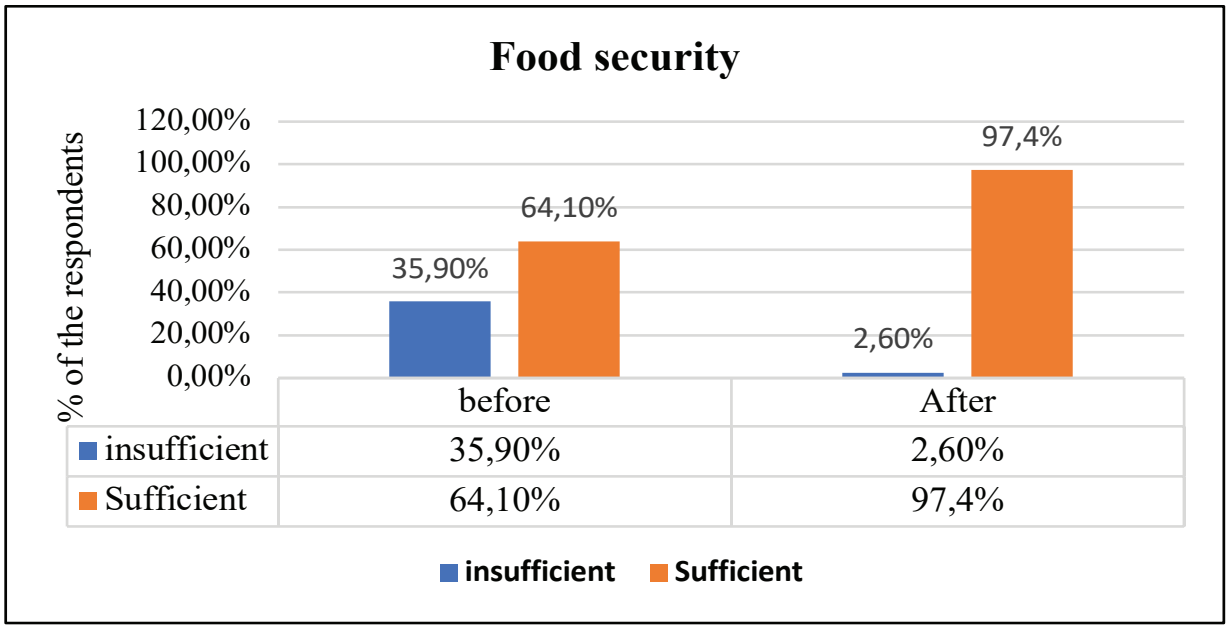

Figure 4. The respondents' response on food security before and after the bridge

One of the local community members interviewed said *"for us who have lands on the other side of the river, during the river flooding could not go there for harvesting, therefore our farm products were either stolen or spoiled. Now that we have a bridge we can harvest our crop anytime and take them to the market without any delays"*. Another respondent commenting on the same matter said*" I have farming plots on the other side of the river, when the river flooded, we could not cross and we would go to bed empty stomach. But now, no matter how the river flood, it does not affect the bridge."* One of the interviewees said *"before the trail bridge, sometimes, the existing wooden planks-made bridge would be washed away by the river, and it would take 2 months to build another one. This affected the access to the market, the availability of the food, access to schools and health center"*.

"Farmers get enough manpower, because people can cross the river safely all the time, hence they cultivate, plants the seeds and harvest on time. Farmers are also able to take their dairy products to the market and milk collection center." this was said by one of the sector executive secretary interviewed.

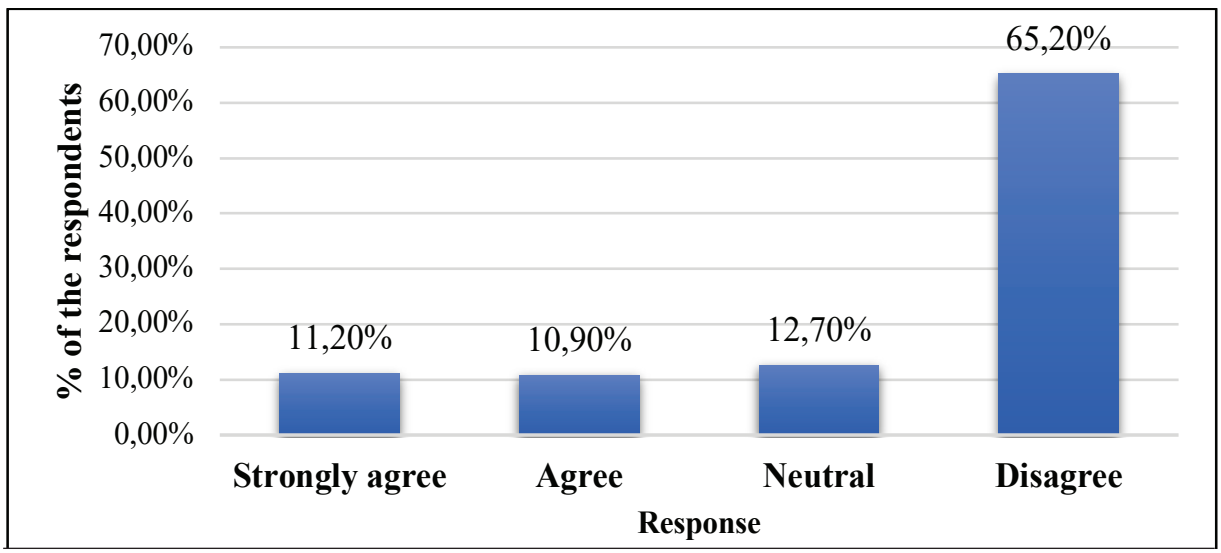

Figure 5. Creation of new economic activity

The Figure 5 above shows the views of the respondents on how the bridge allowed them to create new economic activities. 22.1% agreed that bridges allowed them to create a new economic activity.

One woman interviewed at Gaseke said *"Now that we have that safe bridge, beside the farm activities, I started making sorghum wine commonly known as "ikigage", because I have many customers from across the river and I know that they are able to come anytime whether it is raining or not"*. Another woman interviewed at Kwiterambere said *"After the establishment of the bridge, I started a small business of sell fruits at Kwiterambere market which would not have been possible without a bridge"*.

Table 3. Regression output: the respondents with new economic activities and the travel time after the travel bridge

Regression Statistics	
Multiple R	0.792507147
R Square	0.628067578
Adjusted R Square	0.442101366
Standard Error	0.078844943
Observations	4

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.0209952	0.020995295	3.377321	0.207492853
Residual	2	0.0124330 5	0.006217		
Total	3	0.0334282 5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.21725	0.0965649 39	2.249781	0.153375	-0.1982354	0.632735 54	-0.198235 4	0.632735 4
Times in minutes	-0.00216	0.0011753 51	-1.837749	0.207493	-0.0072171 27	0.002897 71	-0.007217 13	0.002897 13

The Table 3 above depicts the regression output with new economic activities as dependent variable and travel time after the establishment of the trail bridge as independent variable. The R square= 0.62806, it means that the change in new economic activities is driven by the travel time. The significance F is 0.207, and is clearly greater than 0.05, this means there is no linear relationship. Considering the coefficients; -0.00216 means that there is a negative relationship between travel time and creation of new economic activities, and the correlation is strong as shown by the value of Multiple R=0.79. This means that the more the travel time, the less the possibility of new economic activities.

Lieuw-Kie-Song discovered that for every job created in the construction sector, one additional job is created in other related sectors (Lieuw-Kie-Song, Abebe, Sempundu, & Bynens, 2019).

The construction of the trail bridges generated different other jobs; during the bridge construction of bridges themselves, as the local community members obtained job as skilled and non-skilled laborer; 20.2% of the respondents have confirmed to have participated in the trail bridge construction. A district engineer said "*Laborers are chosen from the community where the bridge is going to be built. This allow them to gain money for their economic development and knowledge. It also makes them own the bridge and feel responsible for its sustainable use"*.

Besides the jobs at the bridge construction sites, people had the opportunity to find new jobs. Some of them because of the knowledge acquired while participating in bridge construction (knowledge transfer) as 13.5% of the respondents have affirmed to have gained knowledge from the bridge construction, and one of them affirm to have gained expertise in trail bridge construction to the extent of being called from time to time to supervise other bridge construction sites. Another reason behind new jobs is the insurance in permanent (all-seasons) safe crossing provided by the trail bridge. Figure 2 shows that 13.3% of the respondents use the bridge to go to their jobs. These are the jobs other than farm activities. one of the interviewees who is a teacher and a user of Gitwa Bridge said "*before the trail bridge, I would not have applied for that job at a school located at the other side of the river, because I was sure it could not be possible for me to attend the work during heavy rain causing the river to overflow"*.

Table 4. Regression output: respondents with new job and the travel time after the bridge

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.808769
R Square	0.654107
Adjusted R Square	0.481161
Standard Error	0.058133
Observations	4

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.012782	0.012782	3.782138	0.191231
Residual	2	0.006759	0.003379		
Total	3	0.01954			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.1704	0.071198	2.393319	0.13907	-0.13594	0.476741	-0.13594	0.476741
Times in minutes	-0.00169	0.000867	-1.94477	0.191231	-0.00541	0.002043	-0.00541	0.002043

The Table 4 above is the regression output of the respondents with new job as dependent variable and travel time after the establishment of the trail bridge as independent variable. The R square= 0.654, it means that the change in new job is driven by the travel time. The significance F is 0.191, and is obviously greater than 0.05, this means no linear relationship

between new job and travel time. Considering the coefficients; -0.000169means that there is a negative relationship between travel time and obtention of new job, and the value of Multiple R=0.808 shows a strong correlation.

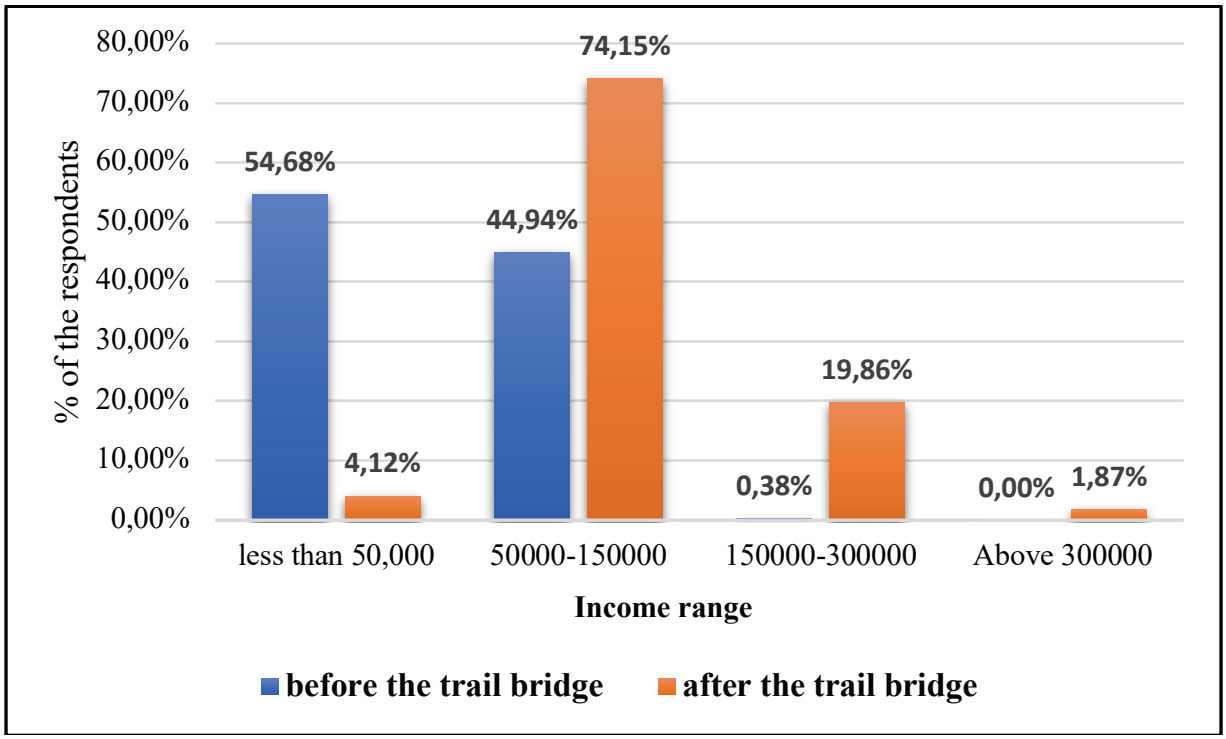

Figure 6. Monthly average income

We observe an increase in income after the bridge. New economic activities and new Jobs created/found have a role to play. Besides, since the majority of the population and the respondents are farmers, all-season safe access to the market, granted by the trail bridges, facilitating farmers to take their products to the market, contributed to the increase of the income. However, we cannot conclude more on how significant the increase in the income is, because of factors such as inflation (2022).

- **Functionality**

In this research we have found that trail bridges that are between 2-3 years old are in very good conditions. Trail bridges that are above 4years old and have timber walkways are ranked from fair to bad (Table 3* in supporting documents), bridges under this category, such as Gaseke and Taba, that are found to be in good conditions, are maintained regularly or have been maintained recently. By observation we have found that trail bridges that are decked with steel structures are in very good conditions, and those decked with timbers are in bad conditions or out of service. This is because timber decks need frequent maintenance and replacement (Shrestha, 2016). Having a bridge under this study that was found to be completely out of use, shows the impact a lack of timely maintenance may have on the functionality of a trail bridge.

Therefore, some of the factors that contribute to the sustainability and full functionality of a trail bridge are the materials used in construction and the regularity of the maintenance (Helvetas, 2010) (Budha & Joshi, 2022). Another factor that contribute to the sustainability of the trail bridge is the efficient use of the trail bridge that is enhanced by the involvement of the local community (Westerink & Barco, 2016). 99.2% of the respondents, affirmed to use the trail bridge during

rainy and sunny periods, this prove that a trail bridge provides an all-season safe crossing. However, the 0.8% of the respondents who said to use the trail bridges in dry period, because the area around the bridge get flooded due to the absence of the drainage in the sugar cane plantation around the bridge, shows that some external factors can disturb the good functionality of a bridge and prevent it from fulfilling the purpose it was constructed for.

The trail bridge sustains the crossing of pedestrians of all categories of age; it means from kids to elders. In addition to that, trail bridge is designed to allow the crossing of animals, motorcycles and bicycles (Westerink & Barco, 2016) (Thomas, et al., 2021). However, the crossing of the motorcycles and bicycles is influenced by the conditions of the roads, paths or trails leading to the bridges. Not having the paths/trails in good conditions indirectly limit the functionality of the trail bridge.

4. Conclusion

In this study of assessing if trail bridges could enhance the environmental aesthetic value and the economic development in the rural areas, the Northern province of Rwanda was taken as case study.

It was found that Gakenke and Rulindo districts are the districts that has the most trail bridges built so far, totalling 75% of all the bridges built in the Northern province. There is a significant increase in building trail bridges with years; 65% of the total trail bridges were built in only two years (2021 and 2022). The trail bridge sustains the crossing of pedestrians of all categories and is also designed to allow the crossing of animals, motorcycles and bicycles.

The sustainability and full functionality of a trail bridge are influenced by several factors such as, the materials used in construction, the regularity of the maintenance and the efficient use of the bridge. Therefore, trail bridges that are decked with steel structures are in very good conditions, while those decked with timbers are in bad conditions. Citizens have all-season safe access to the market, granted by the trail bridges, facilitating farmers to take their products to the market, contributed to the increase of the income, and food security and Job creation
Furthermore, trail bridges contribute to the aesthetic of environment and stream water ecology.

Recommendations

Trail bridges have a positive influence on the aesthetic of the environment and on the economic development of the rural communities. However, for the impact of a bridge to be sustainable, the bridge itself need to be sustainable. To ensure the sustainability of the trail bridge, we would recommend the districts:
• Plan for the regular maintenances
• Repair the bridges that are found to be in bad conditions, before they get completely out of use,
• Enforce the security around the trail bridges using professional night patrol known as “Irondo ry’umwuga”.,
• Where possible, improve the trails and paths to allow motorcycles and bicycles to reach the trail bridges and cross.

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Conflict of interest: We declare the following **interests:** Co-author Diane Sine Ntaganzwa is a staff of Bridges to Prosperity, a non-profit organization that build bridges
Funding: The study received no specific financial support from anyone.
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