Advancing Sustainable Trade Networks in Developing Regions:

On the Ethicality of Solar Powered Autonomous Aircraft in Facilitating West African Intra-Regional Trade of Agricultural Commodities

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I. Introduction

Regional trade in Africa is an underutilized avenue for development. As of 2022, regional trade comprised only 12% of Africa's economic activity. To compare, in the same year, Europe's regional trade made up 60% of its economic activity and 40% in Asia. The main barrier to intra-regional economic activity in Africa is the inadequacy of local road and rail networks. Restrictive border crossings and bureaucratic formalities create challenges for scheduled shipment ("Better transport", 2020).

Trade in West Africa, a developing region, is growing in its dependence on aerial carriage of goods. Research shows that its economic growth and the availability of air transport are directly related (Button et. al., 2015). Simultaneously, drone manufacturers are increasingly deploying Unmanned Aerial Vehicles ("UAVs") for commodity transport in developed nations (Cvitanić & Dražen, 2020). These drone manufacturers are experiencing a rapid explosion of sustainable aviation and battery technology, leading many to produce high-endurance solar powered products. These two coincident trends, the growing need for more expedient forms of commodity transport in a developing West Africa and the improvement of sustainable, low-cost, high-endurance drone technology, are the motivation for this study. The question is whether there is an ethical path between drone manufacturers and users for implementing UAV carriage of goods in West Africa.

The central claim of this research is that ethical integration of solar powered drones in West Africa is not only possible but can be executed practically, sustainably, and morally.

II. Problem Definition

This study focuses specifically on the trade of agricultural commodities in West Africa and its potential facilitation by solar drone networks. The question I am trying to answer: to what extent would the advent of sustainable, low-cost solar drones serve as a viable method for transport in underdeveloped West African regions? UAVs are not restricted by road and rail networks, nor do they necessitate ground border checks. Solar UAVs would boast comparatively low-cost operations and would require minimal pre-existing electrical or storage facilities since they charge in their environment and would remain in the air almost indefinitely. I aim to explore what would qualify an ethical integration of these vehicles in West African regions, if one is possible at all. This research will identify the potential effects of unmanned aerial trade on local economies and border and airspace policies.

Background

The policy in West Africa during the post-colonial period has been marked by a tension between fostering regional integration and navigating global economic dependency. Structural adjustment programs in the 1980s and 1990s, however, under pressure from international lenders, changed policies toward liberalization, while efforts such as the Economic Community of West African States (ECOWAS), represent a continued focus on regional trade cooperation in the face of persistent challenges of infrastructure, political alignment, and external market dependencies. Laroche Dupraz and Postolle (2013) discuss what difficulties West African agriculture is facing under the background of trade policies. In the context of EPA negotiations with the European Union, West African initiatives were born for a regional agricultural policy, ECOWAP, focusing on food self-sufficiency. It marked a turning point for this period, indicating that West African

countries desire to draw a balance between their commitments to external trade and protection of their internal agricultural sectors and food security.

Agricultural trade facilitation is not the first topic of conversation concerning the ethicality of developed infrastructure integration in a developing region. Brewer et al. (2005) discuss the ethical integration of information and communication technologies (ICT) in developing regions, focusing on specific case studies in West Africa. Their conclusions about facilitating spread of information help inform how we might think about facilitating trade, or the spread of physical goods. The authors of the 2005 study conclude that, often, "first world" technologies are expensive, power-hungry, and have different intended uses than what is practical in developing regions. However, the study suggests that through lower computing costs, a shared infrastructure is possible and can be beneficial to the region. It shows that, for ICT, communal technology (kiosks, shared phones, etc.) is more economically sustainable than personal tech, and that, specifically in West Africa, the rise of ICT accessibility has greatly improved connectivity for local government, education, and medical services. In a specific case, increased connectivity played a large part in controlling river blindness, a parasitic disease, in the West African region.

Tolcha et al. (2021) detail the recent liberalization of air transport policy in Africa as a whole, quantifying and relating scores for liberalization, connectivity, economic freedom, and development in 52 countries. Of the five consolidated African regions–Northern, Southern, Western, Eastern, and Central–West Africa consistently performed below the mean for all scores except economic freedom. The study concludes that there is a significant positive correlation between aviation liberalization, connectivity, and economic freedom. West Africa's low scores in

both liberalization and connectivity indicate that its channels for economic growth are not being fully harnessed by current policy-makers. Further, surveys described in the work of Lihoussou et al. (2024), on the competitiveness of air transport in West Africa, demonstrate discontent with inefficiencies in current air transport services among West African people and ultimately encourage industry liberalization. This indicates that the general West African populus is not opposed to the expansion of aerial networks that increase transport efficiency. These sentiments inform how integration of UAVs into existing transport frameworks might be necessary and received positively.

III. Research Approach

The approach for this investigation is threefold. We require a grounding of the research in a holistic background of post-colonial West African economics and the current state of trade policy. We should identify to what extent current conditions meet social needs or demonstrate systematic shortcomings. Second, we should apply the framework of commodity chain analysis to a specific agricultural good and note barriers to optimal exchange. Third, we should examine the potential consequences, positive and negative, of the introduction of sustainable aerial transport technology in the West African region. Such effects may include economic growth or suppression, exposed avenues for corruption, governmental and military acceptance or aggravation, and social assimilation or friction. Finally, conclusions should be drawn about the extent to which ethical integration of sustainable drone transport is feasible.

Note that in discussing literature on sustainable drones, we will use the industry term "high altitude long endurance (HALE) UAVs" to refer to the vehicles.

To accurately identify the barriers to efficient intra-regional trade in West Africa, we should closely follow a product of interest from its initial production to final sale. We can employ the strategy known as commodity chain analysis to examine key points of transaction and transit in the supply chain of a particular product. The goal of this approach is to note points of friction or aberration compared to what is historically good economic practice. A suitable commodity of interest for our agricultural lens is one which is regionally characteristic, that is, a local crop or good which is not heavily imported and is therefore traded mostly within the region.

Coulibaly et al. (2014) detail the agri-food chain for cassava, a yuca-like crop common in West Africa. Cassava plants are grown on local, typically small, farms and shipped either "wet" (just as they were harvested), dried, or processed. The specific cassava crop from the 2014 study was grown in Sierra Leone. Like other agricultural commodities in West Africa, cassava is shipped mainly by road and rail. Bureaucratic formalities and corrupt policy makes border-crossing incredibly slow, but it is necessary to ship internationally given the close-knit geography of the region. If the crop is wet on arrival, it is dried or processed into cassava products at regional factories and plants. The product is then received by local vendors, often paid for with spontaneous "spot transactions." These transactions are procedurally unofficial, subject to negotiation and potential corruption. Finally, the cassava is sold to businesses or at markets to local consumers.

IV. Results

There is a necessary distinction to be made between the practicality and ethicality of expanding solar drone technology into West African agricultural trade. If proper methodology is not

considered for this new technology's integration, we may experience outcomes which are practical but unethical or ones which are ethical but impractical. A practical trade network solution is one which improves the overall intra-regional economic activity in West Africa and spurs further production and distribution of goods. It is one which decreases transit time and cost for agri-food chains and does not require new exorbitantly priced facilities. Simultaneously, an ethical trade network solution is one which only increases interacting parties' quality of life. It is one which does not exacerbate wealth inequality, endanger civilians either directly through malfunction or food insecurity or indirectly by engendering conflict or corruption, or concentrate power into the hands of untrusted agents. An ethical solution is one which people generally desire to conform with and which protects the security of common human rights.

Practically, the results are fairly clear: ever-improving battery technology means electric aviation technology is becoming cheaper and lower maintenance. According to Button et al. (2015), improved transport networks have the potential to facilitate economic growth; efficient air transport speeds up regional trade connectivity. UAVs will simplify the logistics for agricultural commerce and overcome bureaucratic inefficiencies already at hand. According to Cvitanić (2020), the benefits of transport drones are correlated with the reduction of time and transportation costs. It seems that UAVs could mean quicker, more reliable transportation of goods, which is especially paramount for the exchange of such commodities as perishable and vital as food. One might point to the slow rate of climb and speeds to achieve high altitude cruise as a downside of employing sustainable drones for perishable transport; however, since solar drones require no refueling or driver change (not to mention bypassing infrastructural

bottlenecks and the relative proximity of West African nations), the difference in transport time will favor drones.

By adopting UAV technology, local farmers may have an option to reach wider markets and better sales. Frulla and Cestino (2008) explicitly illustrate the development of HALE UAVs as affordable solutions with potential uses in transport of merchandise. Such technology would offer an environmentally mindful alternative for transportation over longer distances than what is presently available, reducing reliance on low-efficiency modes of transportation and even enhancing the competitiveness of local economies with increased activity. A reliable means of transport would contribute to local agricultural sectors' economic sustainability. This is especially valuable in conditions of regulatory pressure under policies such as ECOWAP focused on maintaining food self sufficiency. Along the same vein, Kolade et al. (2022) demonstrate the technological readiness of African stakeholders. Their work shows that investment in education and supportive policy may welcome the local adoption of UAV technology into trade networks.

To avoid concentration of power into the hands of untrusted agents, a decentralized model of power might be employed. We can glean some insight from the case of ICT development in West Africa about a potential ethical avenue for integrating a drone transport network. For any network, whether it is information or agricultural commodities being transmitted, it seems a shared infrastructure with communal access points is important to yield sustainable economic activity. The intrinsic power associated with technology and who controls it needs to be spread among its users to avoid exploitation by a few.

Conclusion

Integration of sustainable UAV transport in West Africa for agricultural commodities appears to be a valid opportunity to enhance prospects for local economies by facilitating access to markets, reducing transportation costs, and increasing regional economic resilience. Through trade regulations like ECOWAP and surveys of public sentiment toward air transport, it is apparent that West African society would largely welcome any uptick in aerial trade efficiency. The combined need for high-volume transport of perishable agricultural commodities in West Africa and high probability for quick assimilation of low-maintenance drones into local society and infrastructure shows promise for the application of HALE UAVs in this context. Further work remains to be done as to the precise details of governing national agencies and regional policy negotiations. Overall, though, the STS research implies that sustainable transport technology may not only be practically feasible but socially workable as well. In developing regions, a new avenue for sustainable economic transport by plane could mean better access to regional trade and increased economic activity. Further, it boasts the potential to reduce border conflicts and supply chain corruption.

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Sociotechnical Synthesis

The objective of my capstone design project was to design a fully solar powered unmanned aerial vehicle (UAV). The topic of my STS project has been to explore the ethics of integrating a fleet of sustainable UAVs for the transport of agricultural goods in West Africa. Comparing the two, my capstone design project aims to answer how to build a mode of transport, while my STS project aims to answer how that mode of transport might be ethically integrated in a particular region.

While strides have been made with hybrid (electric/combustion) engines and Sustainable Aviation Fuel (SAF) technologies, these solutions alone remain insufficient for achieving full decarbonization and zero-emission aviation. Despite the advances in traditional propulsion technology which have allowed for more efficient engines, jet powered and piston aircraft still rely on traditional fossil fuels. Use of fossil fuels leads to the emission of chemicals like nitrogen oxides (NOx), which have detrimental effects. The present technical research focuses on developing a solar-powered, autonomous aircraft specially designed for surveillance and exploration missions. The design approach taken will directly translate to autonomous cargo platforms, as the aircraft will require little maintenance and be capable of high endurance missions. By targeting smaller unmanned applications, we address a more achievable domain for solar-powered flight, as lighter-payload aircraft have lower power and endurance requirements. This goal represents a stepping stone that will drive continued innovation in sustainable aviation technology.

Though the immediate objective of the present research is to design a sustainable aircraft for reconnaissance, the overall implications of its modular design extend to commercial transport.

Especially as the energy density of experimental batteries and solar cells improves, the viability of applying sustainable aviation technology to the carriage of goods will rise. The effects (and, therefore, I argue, the benefits) of this low-maintenance vehicle for trade will be experienced most deeply in geographic regions where there is both a lack of pre-existing regional trade infrastructure and a growing need for the exchange of goods. West Sub-Saharan Africa fits these two descriptors.

In exploring STS implications for sustainable transport technology, I focused on the post-colonial history of West Africa, commodity chain analysis for a specific agricultural good and its barriers to efficient exchange, and potential social consequences for sustainable aerial transport technology. These foci would provide a holistic view of social sentiments toward trade and technology in West Africa as well as the exchange processes which require the most improvement. Commodity chain analysis was appropriate for my topic because it would trace the exchange of an agricultural good from inception to consumption, illuminating points of friction or places where new technology would especially harm or benefit people involved. Integration of sustainable UAV transport in West Africa for agricultural commodities was found to be a valid opportunity to enhance prospects for local economies by facilitating access to markets, reducing transportation costs, and increasing regional economic resilience. Through trade regulations like ECOWAP and surveys of public sentiment toward air transport, it is apparent that West African society would largely welcome any uptick in aerial trade efficiency. The combined need for high-volume transport of perishable agricultural commodities in West Africa and high probability for quick assimilation of low-maintenance drones into local society and infrastructure showed promise for the application of HALE UAVs.

In tandem, the work done in both the capstone project and the STS research imply that sustainable transport technology may not only be practically feasible but socially workable as well. In developing regions, a new avenue for sustainable economic transport by plane could mean better access to food, life-saving supplies, or other important goods. Further, it boasts the potential to reduce border conflicts and supply chain corruption.