Written Report

Title of Written Report:	**Designing a Tuberculosis Treatment Supply Chain in Remote Regions of Papua New Guinea**
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Problem statement

In 1999, the World Health Organization (WHO) declared a tuberculosis (TB) crisis in the Western Pacific Region, which accounted for 19% of the global TB burden (World Health Organization, 2013). According to the Global Tuberculosis Report 2022, Papua New Guinea (PNG) still has the highest TB incident rate in the WPR with 30,000 new cases per year. Caused by the Mycobacterium tuberculosis bacterium and transmitted through the air by coughing, sneezing, laughing, or singing, this disease leads to the death in 50% of cases. However, approximately 85% of people can be cured if they get the currently recommended 4–6-month course of anti-TB drug treatment (World Health Organization, 2022).

Universal health coverage is significantly hampered in the challenging terrain of PNG, where vast tropical rainforests, rugged mountains, and isolated communities dominate the landscape. While residents in large cities can use multiple modes of transport, in rural areas access to health and social services is very limited due to inadequate maintenance, significant fragmentation, and frequent impassability of the road systems during and after rainy periods (Gibson and Rozelle, 2003). For example, after months of rain the clay road between Port Moresby, capital of PNG, and the remote Gulf Province has turned to deep mud and Kikori hospital could not be reached by road. Moreover, the use of inland waterway transport is also not recommended due to the frequent hazards posed by the Coral Sea and the presence of large crocodiles in rivers (Médecins Sans Frontières, 2014).

In this context, the efficiency and effectiveness of the humanitarian supply chain in the response phase emerge as pivotal factors that have profound implications for managing the impact of this biological disaster. Nevertheless, technologically advanced solutions are continuously being developed to ensure the timely and equitable distribution of medical supplies to the affected population in remote areas in relief operation.

Solution development and implementation

To maximize the number of patients receiving TB therapy in remote areas of PNG, integration of technologies into the humanitarian relief chain plays a critical role. Recently, unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs) have gained interest from academia, and humanitarian organizations (Van Wynsberghe and Comes, 2019). To prove the potential of these technologies related to the identified problem, we developed a systematic approach based on data from academic researchers and interviews with humanitarians.

UAVs, also known as drones, are aircraft which operate with no onboard pilot (Juul, 2015). They consist of different sensors that can capture visual and audio data for monitoring and mapping operations (Tang and Veelenturf, 2019). According to a 2016 Swiss Foundation for Mine Actions, one of the most promising uses of drones in the humanitarian sector is to deliver essential items to remote or hard-to-access locations (Soesilo et al., 2016). In order to effectively use them, the path must be planned: this may include obstacles or unknown terrain. There are two ways to manage these problems: Motion path planning, which wants to cover the specified terrain between two points, and coverage path planning (CPP), which finds an optimal collision-free path for the drone over each point in an area of interest in the given environment (Maaj and Landa-Silva, 2023). Additionally, drones can operate under time pressure which is necessary in the response phase by delivering anti-TB drugs to the affected population (Azmat and Kummer, 2020). According to interviews conducted with humanitarian workers, each drone requires only 15 minutes to travel between stations situated 10 kilometers apart compared to the conventional modes of transportation, which take 1 to 2 hours in a very difficult topography. Furthermore, the interviewee Hemand Bogati says that the drone-based delivery is not only faster, but also more cost-effective compared to traditional aid delivery services (see Appendix A). For example, Matternet estimates it would cost $900,000 to operate 50 base stations and 150 drones, which is only 24 cents per flight (Choi-Fitzpatrick et al., 2016).

UGVs are defined as vehicles with nobody aboard and that are, in contrast to UAVs, driving on the ground and not in the air (Man, Koonjul & Nagowah 2018). In comparison to the UAV, the UGV has the advantage of being able to carry a higher amount of cargo as well as being able to directly react to possible activities on the ground (Li, Zhao & Liu 2022). Furthermore, driver and skilled workforce shortage problems can be solved by integrating UGVs into the relief chain (see Appendix A). However, the UGV is slower than the UAV, which needs to be taken into consideration (Li, Zhao & Liu 2022).

As mentioned above, we developed the emergency response system concept for the integration of autonomous vehicles and drones to deliver medical supplies to patients in PNG that are otherwise geographically inaccessible (see Appendix B). Kikori district was selected as a pilot region to serve as a test area that allows for the demonstration of a concept and assessment of feasibility before implementing it on a larger scale (see Appendix C). This region is located in the Gulf Province of PNG and is inhabited by a network of villages scattered along the river delta system. The TB incidence is about 1,290 cases per 100,000 people, indicating an exceptionally high prevalence (Cross et al., 2014). To maintain a consistent supply of TB-related items and prevent shortages that could hinder effective treatment, in-kind donations, purchased supplies and pre-positioned stocks are shipped from various worldwide locations to the point of entry located near Moro Airport. Autonomous vehicles can be integrated into the downstream supply chain to transport relief items from the airport to the central warehouse located in the Kikori town. All the necessary conditions for the deployment of UGVs, such as availability of road infrastructure and cost-speed balance as a goal in the preparedness phase, are completely met. Based on similar requirements, they can also be used for the shipping service from the central warehouse to the local distribution centers, where the medical supplies in the form of pre-packaged items are poised for immediate use during the response phase. Given the natural environment in this region, the last-mile delivery of lightweight cargo to the geographically dispersed affected populations can be accomplished by UAVs. The integration of drones and decentralized local distribution centers results in quicker response times, shorter delivery routes, lower shipping costs, and reduced environmental footprint.

However, the adoption of autonomous vehicles in humanitarian supply chains also depends on regulations, technology limitations and its attractiveness for stakeholders (see Appendix A). Given the PNG's difficult terrain, the main challenge of UAV is the relatively low energy supply. To avoid this, Li, Zhao and Liu (2022) propose a collaboration between UAVs and UGVs, where the UAV may charge itself repeatedly with help of the UGV, which in this case acts like a "mobile charging station" (Li, Zhao and Liu, 2022). In conclusion, interviewees argue that it may take 3-5 years to find solutions to the main technological limitations.

Stakeholders

In response to the very high prevalence rates of TB in PNG, various stakeholders have come together to combat this public health challenge. The initiative, led by the WHO, involves coordination with governmental health departments, international health organizations, local healthcare providers, pharmaceutical companies, research institutions, and NGOs. For example, to provide systematic TB screening in Daru, small island in southwestern PNG, support was obtained from the World Bank, Australia's Department of Foreign Affairs and Trade, and other implementing partners, such as the Health and HIV Implementation Services Provider, World Vision, the Burnett Institute, Medicins Sans Frontieres, Oil Search Foundation, Daru General Hospital, and the Provincial Health Office. Furthermore, PNG Flying Labs is a local tech hub committed to using drones and technology for social good. Their expertise in UAVs and UGVs can greatly assist in delivering medical supplies and speeding up TB treatment in remote areas, aligning with UN Sustainable Development Goals (SDGs). By collaborating with relevant stakeholders and regulators, they aim to establish a supportive framework for the use of these technologies to enhance healthcare access, making a significant impact in the fight against TB in PNG (Papua New Guinea Flying Labs, n.d.).

UN Sustainable Development Goals

The adoption of the proposed concept offers the potential to fulfill several of the SDGs, which represent a global plan for creating a better world by 2030, adopted by all United Nations member states in 2015 (United Nations, n.d.).

First, our solution directly addresses SDG 3 "Good Health and Well-being" by significantly increasing healthcare accessibility in the country where 80% of people live in remote areas with few or no health facilities. Given unique characteristics of PNG, traditional transportation modes can be slow and unreliable. UGVs and UAVs facilitate the timely and efficient distribution of medical supplies to the areas that otherwise may be difficult to serve and help fulfill the humanitarian principle of humanity. This contributes to the goal of prevention of transmission, control of the TB incidence rate and reduction of mortality.

Second, the solution aligns with SDG 10 "Reduced Inequalities", because the healthcare services and medicines will be equally distributed between urban and remote areas. The incorporation of technologies not only promotes improved health outcomes for underserved communities, but also creates new jobs for local communities, reducing economic inequalities.

Third, it promotes technology which correlates with SDG 9 "Industry, Innovation, and Infrastructure". The use of UAVs and UGVs exemplifies how they help develop sustainable infrastructure, improve communication networks, and increase accessibility to remote areas.

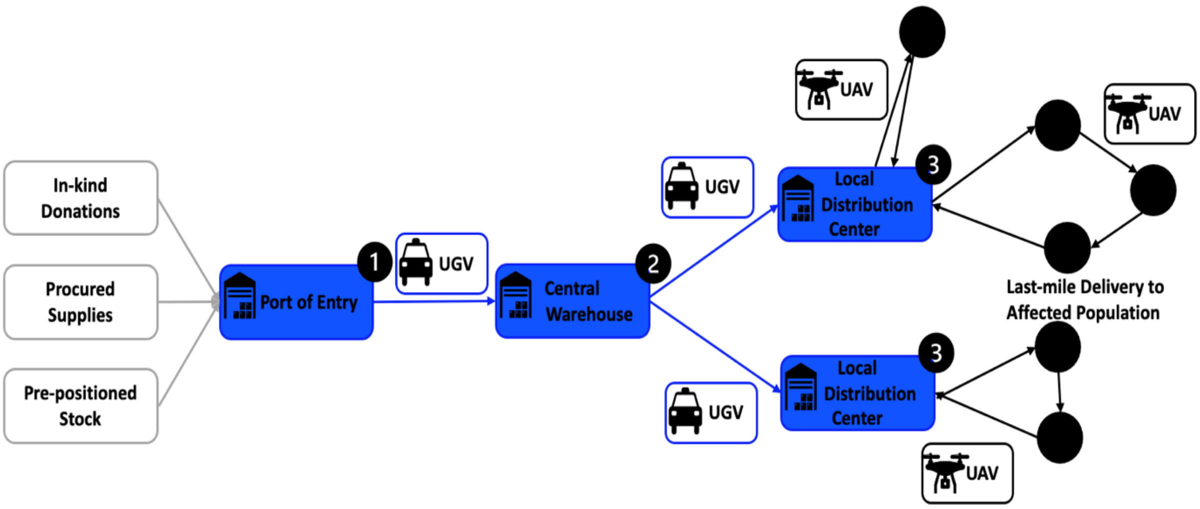
Finally, multi-stakeholder partnerships are essential for putting this solution into practice. Here, we are focusing on SDG 17 "Partnership for the Goals," which stands for a partnership between governments, non-governmental organizations, and technology providers to effectively deploy UAVs and UGVs for healthcare delivery.

Appendix

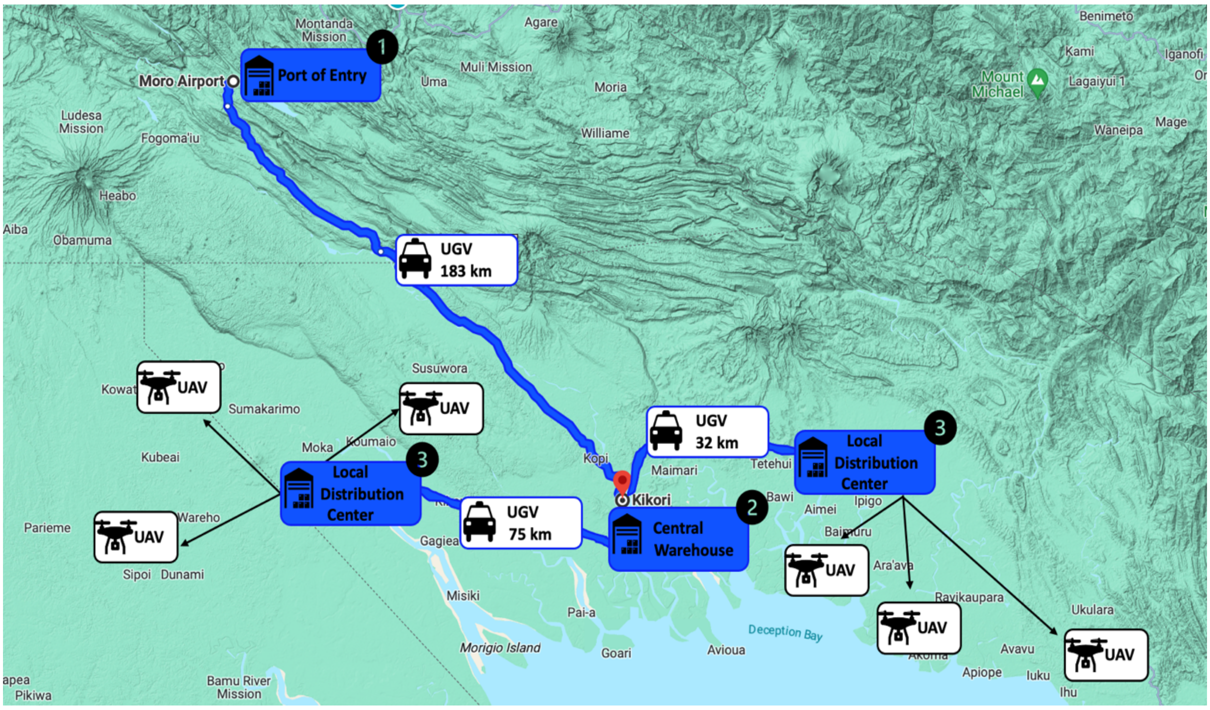
Appendix A: Interview summary

Interviewee (Name, Surname)	Job (Position, Company)	Location (City, Country)	Found via:	Social logistics challenges related to TB in PNG	Advantages of UGVs, UAVs	Disadvantages of UGVs, UAVs	Involved Stakeholders
Hemant Bogati	Tuberculosis Consultant at World Health Organization	Port Moresby, Papua New Guinea	LinkedIn	- Long distances, - Difficult terrain, - Only 3.5% sealed/asphalted roads, - 80% people living in rural areas	- Quick delivery in difficult topography (15 min for 10 km), - Cost-effectiveness: reduced labor, fuel, maintenance costs	- Mature of technology - Privacy concerns - Weather sensitivity	- World Vision - Oil Search Foundation - Child Fund - World Bank - Medicins Sans Frontieres (MSF)
Ipi Noppy	Basic Emergency Life Support Manager at St John Ambulance	Port Moresby, Papua New Guinea	LinkedIn	- Limited health facilities, - Lack of vehicles, - Security issues, - Low literacy rates	- No need for driver workforce, - Flexibility, - Capacity for transportation of heavy or bulky items over rough terrain using UGVs - Capacity for transportation of light/ urgent items over short distances using UAVs	- Requirement of permits or licenses - Short battery life - Low energy supply - Limited payload capacity	- Oil Search Foundation - Burnett Institute - Health and HIV Implementation Services Provider - Suppliers - Donors - Local communities - Volunteers
Ann Clarke	Project Manager at Businesses for Health: Tuberculosis	Port Moresby, Papua New Guinea	LinkedIn	- Poor road infrastructure, - Weather, - Mountainous terrain, - Isolated communities, - Very high TB prevalence rates in rural areas	- Reduced environmental footprint, - Quick transit time, - Accessibility to remote areas in the mountainous terrain	- Technical challenges - Regulatory challenges - Social challenges	- Government - International organizations - Suppliers - Donors - Crowdfunding platforms - Local communities

Appendix B: Systematic approach for integration of UGVs and UAVs into the relief chain



Appendix C: Adoption of UGVs and UAVs for serving the Kikori district



References

Azmat, M., & Kummer, S. (2020). Potential applications of unmanned ground and aerial vehicles to mitigate challenges of transport and logistics-related critical success factors in the Humanitarian Supply Chain. *Asian Journal of Sustainability and Social Responsibility*, *5*(3). https://doi.org/10.1186/s41180-020-0033-7

Choi-Fitzpatrick, A., Chavarria, D., Cychosz, E., Dingens, J. P., Duffey, M., Koebel, K., Siriphanh, S., Tulen, M. Y., Watanabe, H. & Juskauskas, T. (2016). Up in the Air: A Global Estimate of Non-Violent Drone Use 2009-2015. University of San Diego. Retrieved from: https://digital.sandiego.edu/cgi/viewcontent.cgi?article=1000&context=gdl2016report

Cross, G. B., Coles, K., Nikpour, M., Moore, O. A., Denholm, J., McBryde, E. S., Eisen, D. P., Warigi, B., Carter, R., Pandey, S., Harino, P., Siba, P., Coulter, C., Mueller, I., Phuanukoonnon, S. & Pellegrini, M. (2014). TB incidence and characteristics in the remote Gulf Province of Papua New Guinea: A prospective study. BMC Infectious Diseases, 14(1). doi:10.1186/1471-2334-14-93

Gibson, J. & Rozelle, S. (2003). Poverty and Access to Roads in Papua New Guinea. University of WaikatoUniversity of California, Davis. Retrieved from: https://www.journals.uchicago.edu/doi/full/10.1086/380424

Juul, M. (2015). Civil drones in the European Union. Retrieved from: https://www.europarl.europa.eu/RegData/etudes/BRIE/2015/571305/EPRS_BRI(2015)571305_EN.pdf

Lam Loong Man, C. K., Koonjul, Y., & Nagowah, L. (2018). A low cost autonomous unmanned ground vehicle. *Future Computing and Informatics Journal*, *3*, 304–320. https://doi.org/10.1016/j.fcij.2018.10.001

Let’s kick TB out of PNG. (2018). Retrieved from: https://www.who.int/papuanewguinea/news/detail/13-02-2018-let-s-kick-tb-out-of-png

Li, Z., Zhao, W., & Liu, C. (2022). Completion time minimization for UAV-UGV-enabled data collection. *Sensors*, *22*. doi: 10.3390/s22155839

Maaji, S. S., & Landa-Silva, D. (2023). UAV Path Planning for Area Coverage and Energy Consumption in Oil and Gas Exploration Environment. In J. R. Daduna, G. Liedtke, X. Shi, & S. Voß (Eds.), *Computational Logistics 14th international conference, ICCL 2023, Berlin, Germany, September 6-8, 2023, Proceedings* (pp. 467–481). essay, Springer

Médecins Sans Frontières. (2014). Innovating to reach remote TB patients and improve access to treatment. Retrieved from: https://www.msf.org/papua-new-guinea-innovating-reach-remote-tb-patients-and-improve-access-treatment

Papua New Guinea Flying Labs. (2021). Retrieved from: https://flyinglabs.org/png/

Soesilo, D., Meier, P., Lessard-Fontaine, A., Plessis, J. D., Stuhlberger, C., & Fabbroni, V. (2016). Drones in Humanitarian Action » Drones in Humanitarian Action.

Tang, C. & Veelenturf, L. P. (2019). The strategic role of logistics in the industry 4.0 era. In: Transportation Research Part E: Logistics and Transportation Review, Volume 129, September 2019, Pages 1-11. doi: 10.1016/j.tre.2019.06.004

United Nations. (n.d.). United Nations Sustainable Development Goals (SDGs). UNRIC.org. Retrieved from: https://unric.org/en/united-nations-sustainable-development-goals/

Van Wynsberghe, A. & Comes, T. (2019). Drones in humanitarian contexts, robot ethics, and the human–robot interaction. 22, 43-53. doi: 10.1007/s10676-019-09514-1

Viney, K., O'Connor, J., & Wiegandt, A. (2010). The epidemiology of tuberculosis in Pacific Island countries and territories: 2000-2007. Asia Pacific Journal of Public Health, 23(1), 86–99. doi:10.1177/1010539510390671

World Health Organization. (2013). Global tuberculosis report 2013. Retrieved from: https://books.google.at/books?hl=en&lr=&id=1rQXDAAAQBAJ&oi=fnd&pg=PP1&ots=l95a-s4x20&sig=NMOX29FyNa0tl_XLiHqHH1o8l9c&redir_esc=y#v=onepage&q&f=false

World Health Organization. (2022). Global tuberculosis report 2022. Retrieved from: https://www.who.int/teams/global-tuberculosis-programme/tb-reports/global-tuberculosis-report-2022