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RESEARCH ARTICLE

Smarter World Living Lab as an Integrated Approach: Learning How to Improve Quality of Life

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ABSTRACT Implementing smart city projects, encompassing various solutions, addresses urban challenges like traffic, environment, and security. Despite common issues in their effectiveness, this study suggests a living lab approach for smart city development goals. It introduces DDG (Dago. Dipatiukur, and Ganesha) area as an integrated service area, detailing how economic, safety, security, and environmental issues are addressed through this holistic living lab strategy. This research aims to harmonize technological and non-technological innovation to enhance quality of life. It addresses Indonesia's technology gaps as a developing country and leverages its strengths in community-building at the societal level. Aligned with the living lab approach, the successful outcome of this research could pave the way for future technological innovations (e.g., new sensors, applications) and non-technological innovations (e.g., enhanced educational approaches). The living lab research area can be expanded or upgraded to a city scale in the future, requiring coordinated efforts among academics, society, government, etc., including technological feature enhancements. A successful DDG living lab enhances life quality in four stages: planning, construction, operation, and evaluation. Integrating tech and non-tech approaches, prioritizing innovation, community involvement, and literacy is crucial for digitalizing MSMEs, improving mobility safety, and efficient waste-based environmental management. This research successfully integrates technological and non-technological elements to enhance people's lives, utilizing simple sensors at the developmental stage. The cost-effective platform aligns with community-based educational or literacy activities, proving to be an economical approach that conserves government funding. Those responsible for policy can further develop this simple and cost-effective approach.

INDEX TERMS Living lab, smart city, integrated living lab, Bandung.

I. INTRODUCTION

With most of the world's population predicted to live in an urban area by 2050, providing services to fast-growing cities is a race against time. A smarter solution should be devel-

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oped to win the battle against the speed of the problems and challenges cities are facing. The concept of smart cities has gained significant attention in recent years due to the potential benefits it can bring to urban areas. Smart cities use advanced technology and data-driven approaches to improve the quality of life for residents, increase efficiency and sustainability, and enhance economic development.

Current technological advances have led to the advancement of advanced sensors that can drive IoT technology and various other innovations. An example of new progress is in the field of energy, in instrumentation which has enabled secondary electrons to be detected selectively based on their kinetic energy, for example by using a lens detector (TLD) combined with energy filters which are widely available in modern scanning electron microscope (SEMs) [1]. Another example in the environmental sector is the IoT for air pollution monitoring system Mobile kit ''IoT-Mobair'' for prediction using Gas sensors and IoT [2]. Another example in the environmental field is Environmental monitoring using Heterogeneous sensors for W3C standards for interoperability [3]. Various city problems encourage all world researchers to develop various technologies, one of which is IoT.

By integrating various technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data analytics, smart cities can optimize energy usage, reduce traffic congestion, enhance public safety, and provide better access to healthcare, education, and other essential services.

Smart cities have the potential to address many of the challenges faced by rapidly growing urban areas, such as environmental degradation, resource scarcity, and social inequality. Through the use of technology, smart cities can create more efficient and sustainable urban systems, reducing waste and enhancing environmental resilience. Additionally, smart cities can improve access to essential services and opportunities, narrowing the gap between different socio-economic groups and promoting inclusive growth. Overall, the smart city concept has the potential to transform urban areas, making them more livable, sustainable, and equitable for everyone.

In Indonesia, more than 50 cities have embraced the smart city concept, as revealed by the Indonesia Smart City Index 2021. Nevertheless, these cities encounter various challenges in its implementation. These challenges include assessing the suitability of the smart city concept for urban settings, managing the broad scope of implementation, addressing impacts not directly perceived by communities, maintaining a balance between technological advancement and governance, lack of evaluation in urban implementation, insufficient focus on core values over added value, and neglecting sustainability management. Failure to address these challenges properly results in unmet smart city goals. Researchers attribute this failure to inadequate evaluation due to the broad scope and indirect community impacts.

The smart city approach, given its global impact and indirect community perception, remains challenging to implement. Consequently, there is a need for an approach like the living lab model, providing measurable, community-felt solutions that can be swiftly evaluated. The Living Lab (LL) approach involves deploying intelligent solutions in specific real environments, engaging stakeholders for effectiveness measurement, and sustainability feedback. It offers cities a means to enhance residents' quality of life through innovation and experimentation, ensuring solutions align with community needs and preferences.

Living labs serve as testing grounds for refining solutions, fostering innovation, and ultimately leading to more effective urban solutions and improved quality of life. This research aims to address two key questions: how to establish a living lab to enhance quality of life and how to consider the complexity of urban ecosystems when developing living labs, recognizing cities as interconnected, multifaceted systems. By providing a collaborative and inclusive environment for innovation, living labs can help cities to address pressing urban challenges and make meaningful progress toward more sustainable and equitable urban environments.

Based on these problems and the benefits of the living laboratory concept, this research paper answers two research questions. The first question is how a living lab can be built to help improve the quality of life. The Living Labs usually developed and focused on one problem. However, when speaking of a city or area ecosystem, it must consider that cities or area is a complex system and includes various activities, so the components are interconnected.

Therefore, a living lab approach is needed that can solve related city problems, namely how to improve the quality of life. When it comes to quality of life, the SDGs are the basis, namely the economic, social, and ecological understanding. This is why integration is needed Build a small living lab with the Smart City concept. Therefore, the second question of this research is how to build an integrated living laboratory.

Based on the results of the research we conducted, it can be concluded that real world laboratories can be built with 4 main stages that represent how real world laboratories are built with a focus on strengthening MSMEs, society and the environment in that environment in DDG (Dago. Dipatiukur, and Ganesha) area. Meanwhile, real laboratory integration is carried out through the development of a platform that can monitor and provide information to improve the quality of life of people in the area.

The research introduces a groundbreaking approach to smart city development by proposing a living lab methodology as a solution to the challenges faced in implementing various smart solutions for urban problems. Unlike conventional smart city projects, which often fall short in effectively addressing urban issues, this study emphasizes the integration of technological and non-technological innovations through a living lab approach. Particularly, the research focuses on the DDG (Dago. Dipatiukur, and Ganesha) area, showcasing how economic, safety, security, and environmental challenges are tackled using this integrated approach. The study aims to

strike a balance between technological and non-technological advancements to enhance the quality of life, taking into account Indonesia's position as a developing country with a focus on community strengthening. The innovative living lab approach, if successful, is anticipated to pave the way for future developments in both technological innovations, such as new sensors and applications, and non-technological innovations, including enhanced educational approaches.

In line with the living lab methodology, the research emphasizes four key stages—planning, construction, operation, and evaluation—highlighting the importance of community involvement, innovation, and literacy. The integration of technological and non-technological strategies is identified as crucial for achieving the digitalization of MSMEs, improving mobility safety, and implementing effective waste-based environmental management. Notably, the study succeeds in demonstrating that a simple yet unique platform, utilizing cost-effective sensors and aligning with community educational activities, can significantly improve people's lives. This approach, still in the development stage, is proven to be economically efficient and could potentially save government funding. The research suggests that this cost-effective model can be further developed by policymakers for broader implementation, offering a promising solution to the challenges faced in smart city development.

In this study, we, as researchers, have diligently searched through various international studies and have found that:

- There is no research that carries the concept of living lab and smart city which develops technological innovation and community education activities simultaneously or in parallel
- There is no specific living lab and smart city research that actually moves academics, government and society to test innovation together
- There is no special living lab and smart city research that carries out all innovations together with the government and society and then monitored on a platform developed by academics from the beginning of planning until the results are evaluated.

The contribution of this research to the world of science is:

- The contribution of this research to the government lies in enhancing the effectiveness of public policies through direct involvement in the innovation process implemented in the living lab area. This can assist the government in designing and implementing more targeted policies that have a positive impact on society.
- For the community, this research provides benefits in the form of education and training on relevant non-technological innovations tailored to local needs and challenges. With the integrated technology platform, the community can monitor and measure the impact of the implemented innovations, thus providing opportunities for active participation in local development processes.
- In the realm of science, this research contributes new knowledge about the effectiveness of collaboration between academics, government, and society in implementing innovations in limited areas. The research findings can serve as a foundation for further studies on collaborative models in the development and implementation of innovations at both local and national levels.

At the end of the discussion, this research also discuss how the living lab be developed, such as expanding the area, copying it to a new area, or implementing it on a wider scale, namely the city. This also includes how to carry out wider development of the living lab.

As a highlight in the next section, this research try to answer How to Improve Quality of Life from DDG area based on the living lab concept, through the development of platform technology and real programs in the community such as education or literacy. We present this paper with the following structure, in the first part we provide an introduction, problem definition, and our objectives in developing research. In section II, we provide a review of the literature and the methods used. Section III and IV explains the platform development and educational activities for the community that we carried out as results, analysis and discussion. Section V provides the conclusion of all the research activities we carried out.

Novelty Highlights:

- Living Lab Approach: Introducing a living lab methodology for smart city development, specifically tailored to address urban challenges in the DDG area.
- Integration of Technological and Non-Technological Solutions: Harmonizing both technological innovations (e.g., sensors, applications) and non-technological innovations (e.g., educational approaches) to enhance urban quality of life.
- Community-Centric Strategy: Leveraging Indonesia's strengths in community-building to foster societal involvement and support in smart city initiatives.
- Scalability and Collaboration: Proposing a scalable living lab model that can potentially expand to a city-wide scale, requiring coordinated efforts among academia, government, and society.
- Four-Stage Implementation Process: Planning, construction, operation, and evaluation phases ensure a comprehensive and systematic approach to smart city development.
- Emphasis on Innovation and Literacy: Prioritizing innovation and digital literacy to facilitate the digitalization of MSMEs, improve mobility safety, and enhance environmental management practices.
- Cost-Effective Solutions: Demonstrating the efficacy of simple sensors and economical platforms that conserve government funding while optimizing urban services and infrastructure.

- Potential for Policy Development: Offering a practical framework for policymakers to further develop and refine, with the potential to revolutionize urban living standards and sustainability initiatives globally.

II. LITERATURE REVIEW AND BACKGROUND

In this section, the literature review and background provide a comprehensive overview of existing research and contextual information relevant to the study.

Literature Review:

A. SMART CITY CONCEPT

A smart city is a concept that aims to integrate technology and data to improve the quality of life for citizens, enhance sustainability, and streamline city operations. It involves the deployment of various sensors, networks, and data analytics tools to gather real-time information on different aspects of urban life, such as traffic flow, energy consumption, air quality, and public safety. This data is then analyzed to optimize the use of resources, improve urban planning, and provide more efficient services to residents. Smart city initiatives also prioritize citizen engagement and participation, promoting transparency and collaboration between the government, businesses, and communities to create a more livable and inclusive city for all.

Smart City is a city built on the human being. The smartness of a city refers to its ability to promote a lifestyle in which the needs of the individual citizen match those of the community. Smart city has a broad concept and expansive implementation. Over the past decade, there are a lot of definitions of the smart city concept. The term smart city is a city with many complex elements which represent the backbone of a revolution involving modern cities to change the way of life of its citizen [4].

A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens. Smart city generally refers to the search and identification of intelligent solutions which allow modern cities to enhance the quality of the services provided to citizens [5].

The application of information and communications technology (ICT) with their effects on human capital/education, social and relational capital and environmental issues is often indicated by the notion of smart city [6]. Smart cities are now including qualities of people and communities as well as ICTs [7].

Smart cities defined as attaining sustainability of a city with help of modern technologies while the environmental sustainability is an essential target [8].

Consequently, from this diverse definition of a smart city, the components and indicators of a smart city are also complex. There is a multitude of concepts, components, and indicators for Smart Cities. All definition above shows us the smart city component and indicators. Each study also shows us the different approaches and components in the implementation of Smart Cities. How about Indonesia, Indonesia also has an approach, one of the Garuda Smart City Model (GSCF) is a model developed by Smart City and Community Innovation Center in Bandung Institute of Technology based on Sustainable Development Goals, with the GSCF's focus on improving the quality of life, economic, social, and ecological areas. GSCF is the first stage in the development of the real lab to establish the areas and goals of the real lab. In the context of GSCM, a smart city consists of 3 (three) layers. The first layer is resources or resources that have not been processed and become city assets. The second level includes smart people, infrastructure and technology, and governance as enablers for the delivery of services to cities. The third layer is the main domain or component, which consists of the intelligent economy, intelligent society, and intelligent environment, which consists of services according to their respective domains. More details on the services provided by GSCM can be seen in Figure 1. So, in summary, we need to find an approach that can solve the challenge of smart city factors like people, transportation, technology, etc. In this research, we used the living lab as an alternative approach to supporting the goal of smart cities that improve quality of life.

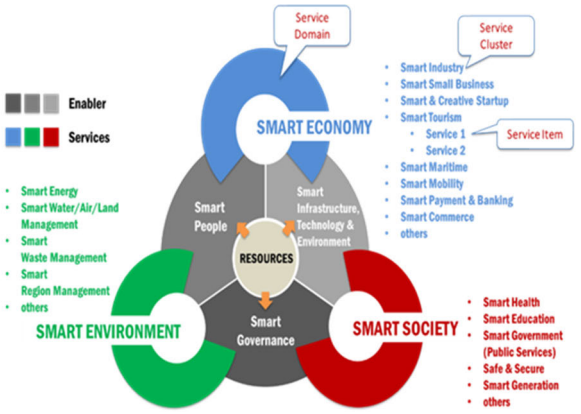

FIGURE 1. Garuda smart city model [9].

The concept of a smart city is to establish a cohesive and interlinked system wherein individuals, technology, and the environment coexist harmoniously to foster economic advancement, environmental sustainability, and an enhanced standard of living for all inhabitants [10].

The first-generation smart city presents the concept of six pillars, including economy, mobility, government, environment, society, and lifestyle [11]. Due to the high rate of urbanization, it is necessary to assess the contribution of platforms to creating new tools for the development of human-centered, smart, sustainable, and resilient cities. This platform is used as a tool in urban community activitie [12].

Several cities in Indonesia have implemented the smart city concept in their city governance. In order to realize a Smart City in the City of Surabaya, it is led by the mayor and all government agencies of the City of Surabaya. One way to

conceptualize a smart city is as an icon of a sustainable and livable city [13].

Platforms must do more heavy lifting and provide general application functionality such as tracking objects in global coordinate space, enabling precise device positioning, and abstracting access to distributed infrastructure [14].

B. SUSTAINABLE CITY

The relationship between a smart city and a sustainable city is inherently intertwined. A smart city leverages advanced technology and data-driven solutions to enhance urban living, optimize resource utilization, and improve the overall quality of life for its residents. In doing so, it often prioritizes sustainability by efficiently managing resources, reducing energy consumption, minimizing environmental impact, and promoting eco-friendly practices. Sustainable city principles, on the other hand, focus on long-term environmental and social well-being by emphasizing responsible resource management, conservation, and a reduced carbon footprint. By integrating smart technologies, data analytics, and IoT (Internet of Things) solutions, a smart city can effectively address sustainability challenges, making it a crucial enabler for building sustainable cities that are environmentally friendly and socially inclusive.

The concept of sustainable cities has gained significant attention in the field of urban planning, as global efforts are being made to tackle environmental issues and establish urban settings that are both habitable and ecologically sound. These urban areas are planned and developed with a holistic strategy emphasizing incorporating sustainable energy sources, effective public transportation networks, ecological landscapes, and environmentally conscious infrastructure. In order to secure the alignment of technical advancements and urban development projects with long-term ecological balance, economic resilience, and societal well-being, smart cities must emphasize sustainability [15]. Implementing smart cities that align with sustainability objectives enhances the overall well-being of individuals and safeguards the ecological, societal, and economic resources [16].

The emergence of the smart notion can be attributed to integrating information technology encompassing hardware, software, and network technology. This integration aims to enhance individuals' cognitive abilities in making informed business process decisions within a collective setting, such as a group or organization. A smart device is a context-aware electronic device capable of performing autonomous computing and connecting to other devices wire or wirelessly for data exchange [17]. Artificial intelligence facilitates the provision of cognitive information to previously non-responsive equipment, thereby enhancing their intelligence. Additionally, gadgets are endowed with computational capabilities and connected to the Internet, forming the Internet of Things (IoT), which enables them to adapt to unforeseen circumstances [18], [19]. Many applications can be found, from small devices to asset tracking devices, including transportation, data management, libraries, trash management, and more. Smart gadgets establish a network connection through several wireless protocols, enabling interactive communication [20], [21], [22].

Sustainability has emerged as an important pillar of modern society, reflecting the urgent need to protect and preserve our planet for future generations [23], [24]. At its core, sustainability is about meeting the needs of the present without compromising the ability of future generations to meet their own needs. It includes a holistic approach to environmental, social, and economic considerations [25]. Sustainable living goes beyond environmental concerns and promotes social equity, fair labor practices, and responsible consumption. As individuals, businesses, and governments increasingly recognize the importance of sustainability, we are witnessing a transformative shift towards greener practices, sustainable development, and the adoption of green policies [26], [27].

Sustainable informatics focuses on optimizing energy efficiency in data centers and IT infrastructure, reducing e-waste through proper recycling and responsible disposal, and promoting using renewable energy sources to power computing processes. In addition, sustainable informatics also emphasizes the development of environmentally friendly software and applications that consume fewer resources and the adoption of cloud-based solutions to optimize resource allocation and reduce hardware requirements. By integrating sustainability into informatics, we can contribute to building a more environmentally conscious and sustainable technological urban planning [28], [29]. The objective of incorporating sustainability into urban planning is to establish a city that prioritizes inclusive growth, equitable resource distribution, safeguarding the entire community's well-being, and ensuring universal accessibility [30].

C. LIVING LAB

A living lab is a research and innovation approach that involves testing new technologies, products, and services in real-world settings to improve the quality of life for people. It provides a platform for collaboration between researchers, businesses, and citizens, where they can co-create, co-design, and evaluate solutions to complex urban challenges. Living labs can be used to test innovations in various domains, such as energy, mobility, health, and education, and involve the active participation of end-users in the design and testing process. The insights and feedback generated from living labs can inform policy decisions, guide the development of new products and services, and help create more sustainable and inclusive cities. By involving citizens in the innovation process, living labs can lead to more user-centered and effective solutions that address the real needs and preferences of people.

Urban Living Labs (ULL) have become a trend in cities all over the world. In urban design, several city planners agree on the importance of understanding those for whom urban projects are designed [31].

Laboratory in English is translated as ''laboratory'', according to the Cambridge Advanced Learner's Dictionary and Thesaurus, the word ''laboratory'' is defined as a room or building with scientific equipment to carry out scientific tests or to teach science, or a place where chemicals or medicines are produced (a room or building with scientific equipment for carrying out scientific tests or for teaching science, or a place where chemicals or medicines are produced).

Living Lab is a living laboratory where the components to be studied in research are carried out in real life. The involvement of not only potential customers but also all other stakeholders along the value chain can be seen as the most important element for the successful operation of the living lab. Living Lab must not only provide access to the advanced technology of one type but often competing technologies provided through different business models [32].

Degree of Participation	Single and Controlled Contexts	Multiple and Emerging Contexts
High: Observation and Creation	Traditional Lab Experimentation	**Living Lab Experimentation**
Low: Observation	Traditional Empirical Social Science Research	Ethnographical Observation

FIGURE 2. Participation in the context of innovation [33].

Traditional empirical social science research has a low observability rate, and traditional laboratory experiments (like a usability lab) have high observability in a single, controlled context. Living lab experiments strive for the same level of observability in an organic multi-contextual space. This means that the clients participating in the Living Lab are observed in many aspects of their lives, such as their role as citizens, workers, at home while traveling, etc. Despite the high level of observation, the use of collaborative ICT on-site tries to follow the Living Labs -Approach to minimize interference. It is Living Labs' human-centric approach that recognizes citizens in civil society as a potential source of innovation. The idea of the Living Laboratory has been continuously expanded and redefined in recent years. Recently, the focus has shifted to the user's active role as a coin creator. Users working in real-world environments are actively encouraged to keep up to date with technological developments and innovations.

In this case, the Living Laboratory was positioned as a platform for user-based innovation. However, as the number of users and organizations involved expands to larger social entities such as local or regional communities, they become more open as more stakeholders become involved. It is therefore important to distinguish between those who are centrally involved as users, developers, or beneficiaries and those who show interest but are outside the innovation [34].

The Living Lab concept is characterized by a ''user as innovator'' approach. This means that ''the basic idea is not about using users as 'guinea pigs' for experimentation, but about getting access to their ideas and knowledge'' [32]. Therefore, researchers need to use methods that allow interaction or a joint creative approach between consumers and researchers during the overall development process. To gain insight into existing Living Lab initiatives, best practices were identified and the various methods used to engage users in these Living Labs were outlined. Because Life Labs are so heterogeneous and have different focuses, it's difficult to compare them. The results provide an overview of existing methods and those available in the Living Lab network.

The Living Lab is a way of working consisting of eight steps, shown in the image on the right. For each of these steps, the most important measures and necessary conditions are presented, along with general recommendations and tips on how to complete these steps [35]. The zigzag lines between the steps emphasize that there are different ways to achieve a successful Living Labor result. However, this way of working in the Living Lab helps the actors involved in the Urban Living Lab to keep the intended step in the innovation process and provides a step-by-step plan that enables a constructive and efficient process towards the Living Lab [35].

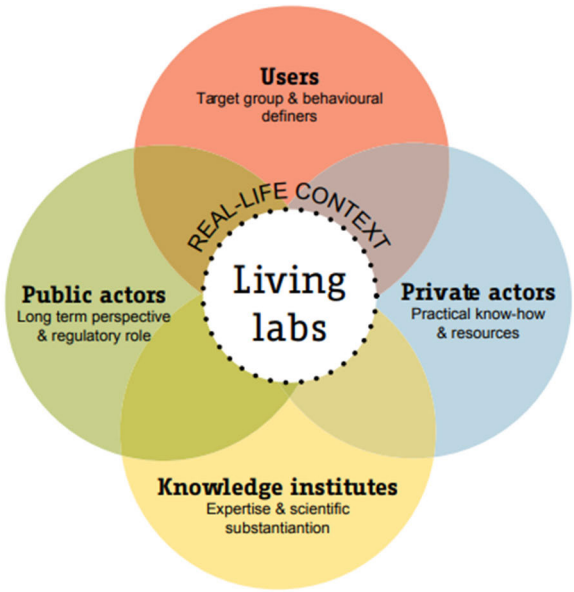

FIGURE 3. Living lab concept [35].

Involvement of all live laboratory stakeholders Whether a project is created or linked to an existing project, it is important that all live laboratory stakeholders are involved from the beginning of the project to achieve a co-created and integrated solution that spreads the live laboratory. This requires that partners initiating the lab actively invite public, private, civil, and knowledge actors to participate in the lab. Note that the involvement of end-users often requires special attention, as these actors usually have no professional motives for participating in the innovation process and participate voluntarily. It should be ensured that all relevant stakeholders

are involved in the context of the problem or the solution sought, regardless of existing networks that may be embedded in collaborative sites or structures.

Ensuring the comprehensive involvement of all stakeholders in the living laboratory is paramount, whether initiating a new project or integrating it with an existing one. This inclusive approach is vital for fostering a co-created, integrated solution that permeates the living laboratory ethos. It necessitates proactive engagement from the outset, wherein the initiating partners actively solicit participation from a spectrum of stakeholders, including public, private, civil, and knowledge-based entities. Notably, particular attention must be directed towards involving end-users, who typically engage in the innovation process without professional incentives and instead participate on a voluntary basis.

Efforts should be made to ensure that all pertinent stakeholders are engaged, regardless of any pre-existing networks or affiliations that may be present within collaborative frameworks or structures. This inclusive stance guarantees that the full spectrum of perspectives and expertise is brought to bear upon both defining the problems at hand and seeking viable solutions. By encompassing diverse voices and insights, the living laboratory stands to benefit from a richer, more nuanced understanding of the challenges it aims to address, thereby enhancing the efficacy and relevance of its endeavors within the broader community.

Living labs have been said to offer multiple benefits to businesses, societies and users. Furthermore, living labs support stakeholders by integrating policymaking and businessdevelopment issues. A wider use of living labs enhances the inclusion and usefulness of their applications in society. Thus, living labs are vital for transforming everyday knowledge generation into models, methods and theories. For example, living labs are particularly valuable to different stakeholders for the opportunities they bring, because they provide the possibility to obtain user feedback and insights, conduct experiments, and involve a number of users in the innovation process [36].

Living labs are understood as spatially and temporally bounded experiments in a real-life setting that facilitate different forms of learning. Participants, such as individuals and households, are seen as cocreators of knowledge on equal grounds with researchers [37].

Multi-method approaches: there is not a single living lab methodology. All living labs combine and customize different methodologies to best fit their purpose; • User-engagement: the users are involved at the beginning of the process and this is the key of success: Multi-stakeholder participation: even if the focus is on users, involving all relevant stakeholders is of crucial importance. This includes representatives of public and private sectors, academia and people, Real-life settings: the very specific characteristic of living labs is that the activities take place in real-life settings to gain a truthful overview of the context, Co-creation: the users become equal contributors rather than subjects of study. They participate as co-creators in a co-design philosophy [38].

There are three main building blocks in a living laboratory project that follow the innovation and development phases: Exploration: it is important to know the current state and plan for possible future states. Is about moving from ideals to concepts or prototype solutions, Experiment: actual testing of what is proposed. The concept was tested by developing and experimenting with prototypes, Evaluation: assessment of the impact of the experiment on the current state to restore the state in the future. The goal is to implement the innovation into the target market by relying on a go-to-market strategy [38].

Background: Smart cities are urban areas that effectively utilize their limited resources to deliver services to residents through the implementation of innovative solutions, with the ultimate goal of enhancing the quality of life for inhabitants.

Living Labs (LL) offer a promising solution to address these challenges by leveraging real-world data and promoting collaboration among various stakeholders. Functioning as platforms for innovation, Living Labs facilitate the establishment of projects guided by the principles of open user innovation, with a primary focus on addressing real-world issues within the local context.

The same case happened in Indonesia, based on data from Indonesia Smart City Index 2021, more than 50 cities in Indonesia are implementing the smart city concept. However, cities faced many challenges in implementation [9]. Some of these challenges are (A) the suitability of the smart city concept for urban conditions, (B) the scope of implementation is too broad (don't assume a limited scope), (C) the impacts are not directly accounted for by the perceived community, (D) too focused on technological development, forgetting governance and changing the mindset of human resources, (E) lack of evaluation of the implementation carried out in the urban area, (F) not starting from the core value, instead focusing on the added value on the implementation, (G) does not manage sustainability. Challenges that arise if not properly managed result in the Smart City goals not being met as mentioned by According to several researchers, the main problems causing this failure were related to the lack of evaluation of the implementation as the scope was too broad and the impacts could not be directly felt by the community [39].

From the above, it can be concluded that the smart city approach is still too big and relatively difficult to implement since its impact is very global and cannot be directly perceived by the community. Hence, we need an approach capable of providing answers to the problems that arise in smart cities. A solution that can be felt by the community is measurable and can be evaluated quickly. And the approach that fits this condition is the living lab approach.

Living Lab (LL) is an approach to solving problems through the deployment of intelligent solutions in a specific place in a real environment, involving stake holders to measure their effectiveness and provide feedback on the sustainability of the improvement from which they derive benefit. The living lab concept could be a good solution for cities to improve the quality of life of its residents by

creating an environment of innovation and experimentation. Living labs offer a space for stakeholders, including citizens, to work together and co-create solutions to urban challenges. By involving local residents in the process, living labs can ensure that the solutions are tailored to the specific needs and preferences of the community, leading to better outcomes and increased adoption rates.

Furthermore, living labs provide an opportunity to test and refine solutions in real-world settings, creating a space for experimentation and innovation. This approach allows cities to try out new ideas in a controlled environment, gather feedback from users, and make necessary improvements based on data and feedback. Ultimately, living labs can help cities to find more effective and efficient solutions to urban challenges, leading to improved quality of life for residents. By providing a collaborative and inclusive environment for innovation, living labs can help cities to address pressing urban challenges and make meaningful progress toward more sustainable and equitable urban environments.

Drawing upon these challenges and the advantages of the living laboratory approach, this study addresses two research inquiries. The initial query pertains to the construction of a living lab aimed at enhancing life quality. Typically, Living Labs are constructed and centered around a singular issue. Nevertheless, when discussing a city or regional ecosystem, it becomes imperative to acknowledge that cities or regions constitute intricate systems comprising diverse activities, thus necessitating interconnected components to be considered.

III. METHOD

Living Lab aims to improve the quality of life with sustainable solutions that provide impact and benefits that citizens can feel directly. We encourage four main activities to establish a Living Lab as a place to test places or incubators for smart solutions used to solve problems. Figure 4 shows the steps.

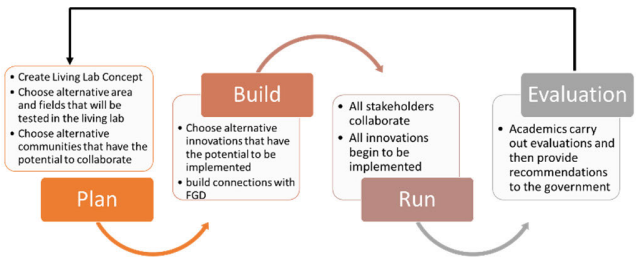

FIGURE 4. The smart world living lab activities.

The main activity to implement the smart world living lab are the process of Plan, Build, Run, Evaluate (PBRE).

- Plan: The initial phase encompasses identifying areas and assessing existing conditions to pinpoint issues and explore alternative solutions. This process relies on direct surveys following the Garuda Smart City model. The outcomes include the selection of the area, the assessment of its current state, and proposals for alternative solutions. During this stage, academic researchers develop the living lab concept, identify potential areas, and collaborate with regional authorities. Additionally, they prepare various innovative solutions and coordinate with governmental bodies.
During the planning phase, the initial steps revolve around a meticulous examination aimed at identifying specific areas within the designated domain and conducting thorough assessments of the prevailing conditions therein. This critical process serves to pinpoint existing issues and lay the groundwork for exploring a myriad of alternative solutions. Central to this endeavor is the utilization of direct surveys, adhering closely to the established framework of the Garuda Smart City model, which serves as a guiding paradigm for effective urban planning and development.
The resultant outcomes of this comprehensive assessment encompass a trifecta of crucial elements: the careful selection of target areas for intervention, a detailed evaluation of their current status quo, and the formulation of innovative proposals outlining alternative avenues for amelioration. Concurrently, within this stage, academic researchers play a pivotal role in conceptualizing and refining the living lab concept, meticulously identifying potential sites ripe for intervention, and engaging in collaborative ventures with regional authorities to ensure alignment with broader developmental goals and regulatory frameworks.
- Build: The subsequent step involves selecting solutions from the alternatives proposed in the planning phase. This leads to the implementation of solutions and involves engagement with stakeholders. The discussions between government officials and academics play a crucial role in deciding which living lab areas are feasible for implementation and what innovations can be pursued.
The dynamic interplay between government officials and academic researchers assumes paramount significance during this juncture, as their collaborative discussions serve as the crucible for delineating the feasibility of potential living lab initiatives and charting the trajectory for innovation endeavors. In essence, these deliberations function as a nexus where theoretical propositions are subjected to pragmatic scrutiny, with a keen eye toward discerning which living lab areas harbor the requisite conditions for successful implementation and which innovations hold the greatest promise for transformative impact.
This phase epitomizes a pivotal juncture wherein abstract concepts are concretized into actionable strategies, propelled forward by collaborative synergy and a shared commitment to effectuating meaningful change within the living lab ecosystem. Through concerted efforts and judicious decision-making, this phase lays the groundwork for the realization of tangible outcomes

that resonate with the overarching objectives of sustainability, inclusivity, and community resilience.

- Run: This phase focuses on either simulating or directly implementing the selected solutions to address area-specific problems. The aim is to apply the solutions within the area. Academic researchers provide community education and communication within the living lab area, supported by government involvement. Educational initiatives for the community receive government backing.

  The ''Run'' phase represents a pivotal stage in the living lab process, transitioning from the deliberative and preparatory phases to the practical execution and application of selected solutions aimed at addressing area-specific challenges. Within this phase, the primary objective is twofold: either to simulate the identified solutions in controlled environments or to directly implement them within the targeted areas, with the overarching aim of effectuating tangible improvements and fostering sustainable change.

  Central to the execution of this phase is the active involvement and collaboration of academic researchers, who serve as key facilitators in orchestrating community engagement and knowledge dissemination initiatives within the living lab milieu. Leveraging their expertise and resources, academic researchers play a multifaceted role in not only overseeing the implementation of selected solutions but also in providing crucial educational outreach programs tailored to the specific needs and dynamics of the local community.

  Moreover, the involvement of governmental entities assumes a pivotal role in bolstering the efficacy and impact of the ''Run'' phase initiatives. Government support and engagement serve as catalysts for ensuring the seamless integration of living lab activities within broader policy frameworks and institutional structures. By lending their endorsement and resources to educational initiatives and community outreach programs, governments play a vital role in amplifying the reach and effectiveness of these endeavors, thereby fostering a conducive environment for knowledge exchange and capacity-building within the community.
- Evaluate: The final activity entails assessing and measuring the outcomes of the implementation process. Positive results and feedback pave the way for potential expansion. Measurement results gauge the impact of implemented solutions on the region's quality of life. Academic researchers conduct an evaluation of the living laboratory process and its success, communicating findings to the government for input and potential policy adjustments. Expansion of the living laboratory area or selection of new areas within the same city may occur, or the government may decide to implement innovations on a city-wide scale.

  Central to the evaluation process is the diligent collection and analysis of data pertaining to the implemented solutions, with a view toward identifying trends, patterns, and areas of improvement. Positive results and feedback garnered from stakeholders serve as invaluable metrics of success, providing valuable insights into the effectiveness of the interventions and paving the way for potential expansion and scaling up of successful initiatives.

  A critical component of the evaluation process involves measuring the tangible impact of the implemented solutions on the region's quality of life. This entails assessing various socio-economic indicators, such as access to essential services, employment opportunities, environmental sustainability, and community well-being, among others. By quantifying the tangible benefits accrued from the initiatives, stakeholders are empowered to make informed decisions regarding future investments and resource allocations.

  Academic researchers play a pivotal role in spearheading the evaluation efforts, drawing upon their expertise in research methodology and data analysis to conduct a thorough assessment of the living laboratory process and its overall success. Through rigorous evaluation methodologies, researchers are able to provide an objective and evidence-based assessment of the efficacy and impact of the initiatives undertaken, thereby informing strategic decision-making and policy formulation.

After all the activities were carried out, the academics who conducted this research provided an evaluation of the process and success of the living laboratory and then communicated it to the government so that the government could get input and new ideas for future policy making. The living laboratory area can be expanded or a new area can be selected in the same city or the government is confident enough to implement the innovation on a city scale depending on the government's decision.

The development of a living lab, in general, involves 4 main stages, but in this study, one additional main stage carried out which is one of the updates of this research, namely the integration of the living lab into a platform to help decision-makers to unite and use living lab data for decision making.

IV. SOCIETY (VIANA SAFE SECURE)

This research aims to investigate the effectiveness and impact of implementing video analytics technology and sound notifications for traffic violators at intersections on road users' awareness and behavior in choosing safer and secure options. By utilizing innovative technology in video analytics, this study will analyze patterns of road user behavior and violations occurring at intersections, as well as identify possible solutions to enhance road safety.

Through a social approach that considers the interaction between technology, human behavior, and the road environment, this research is expected to provide valuable insights to support traffic accident prevention efforts and create a safer

and more comfortable road environment for the community, including by integrating sound notifications that can provide direct warnings to violators, thereby increasing their awareness of safe driving behavior.

In this research, we utilize advanced video analytics technology to identify anomalies, such as violations of vehicle and pedestrian behavior, at designated areas within the video footage. These designated areas serve as detection zones for traffic violations. Once detected by the video analytics system, an alert sound will be triggered at the traffic lights located at the site where the CCTV cameras are installed, providing a warning signal.

This innovative approach aims to enhance road safety by not only identifying violations but also by actively notifying both drivers and pedestrians in real-time about potential risks or breaches of traffic regulations. By integrating sound notifications directly into the traffic infrastructure, we aim to prompt immediate attention and corrective actions from road users, ultimately contributing to the reduction of traffic accidents and fostering a safer urban environment. Through this comprehensive system, we seek to leverage technology to address critical issues in traffic management and promote a culture of compliance and awareness among all road users.

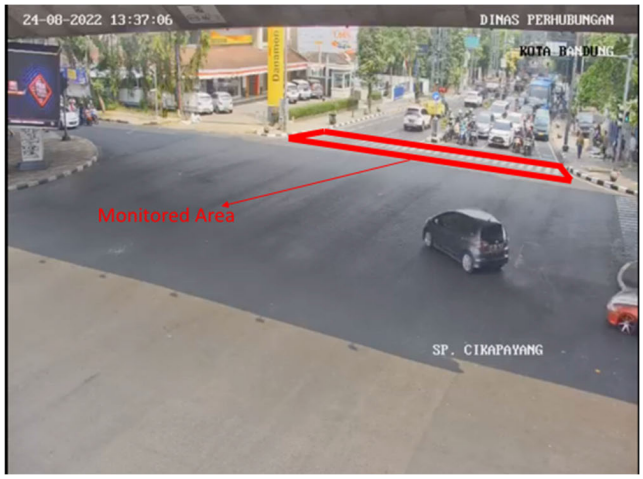

FIGURE 5. Video analytic with ai monitored area.

Below we explain the targets we will pursue to achieve based on official Indonesian government regulations.

The targets in this section are adjusted to government targets and existing conditions in Dago. The targets in this section are adjusted to government targets and existing conditions in Dago. The target in this living lab research is to reduce the number of traffic violations by 28% from the number of violations currently occurring

V. ECONOMY (MSMEs)

The paper aims to address the digital proficiency of Micro, Small, and Medium Enterprises (MSMEs) in DDG through a comprehensive educational approach. Recognizing the significance of digital literacy, the study proposes a series of

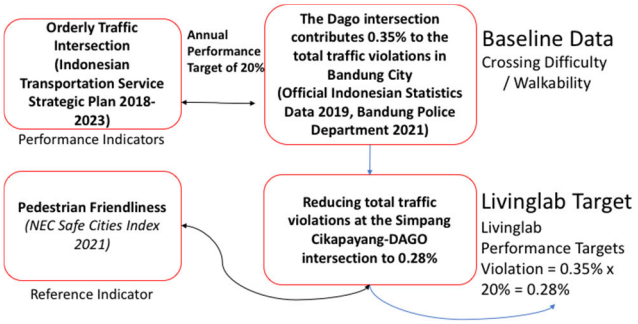

FIGURE 6. Calculation of targets for reducing traffic violations.

training sessions targeting different aspects of technological competency.

- Digital Literacy Training: Providing training on the use of digital devices, internet access, and information management to enhance their technological proficiency.
- Information Competence Training: Training MSMEs in searching for relevant information for their businesses, managing data, and analyzing market trends.
- Communication Competence Training: Teaching effective ways to interact and share information through digital platforms such as social media and instant messaging to expand their business reach.
- Personal and Device Security Education: Providing an understanding of the importance of personal data and digital device security and providing training on securing devices and information.
- Education on Digital Payments: Providing an understanding of the benefits and usage of digital payment methods such as Go Pay, OVO, and QRIS to improve efficiency in business transactions.
- Introduction and Training on E-commerce Usage: Teaching MSMEs about the benefits and methods of using e-commerce platforms such as Tokopedia, Bukalapak, and Shopee to expand market share and increase sales.
- Introduction to Digital Delivery Services: Providing an understanding of the advantages of using digital delivery services such as Go Food, Grab Express, and Go Box to expedite product delivery to customers.
- Smart Economy Development: Encouraging the use of technology in various aspects of business, including marketing, inventory management, and transaction recording to enhance efficiency and competitiveness of MSMEs in the digital era.

VI. ENVIRONMENT (WASTE)

This research endeavors to educate and promote responsible waste disposal practices, emphasizing the importance of both proper disposal and waste segregation. By fostering awareness and understanding among the community regarding the significance of disposing of waste in designated areas, as well

as sorting waste for efficient processing, the aim is to mitigate the volume of waste generated.

Through educational campaigns and interactive initiatives, such as workshops and informational materials, individuals will be encouraged to adopt sustainable habits, including disposing of trash in designated bins and sorting recyclable materials. Furthermore, by instilling the habit of waste segregation at its source, the research seeks to streamline the waste management process, making it more manageable and environmentally sustainable. Ultimately, the overarching goal is to reduce waste accumulation, minimize environmental impact, and pave the way toward a more sustainable and cleaner future.

The waste disposal and segregation education campaign:

1. Importance of Proper Waste Disposal: Discussing the environmental and health consequences of improper waste disposal, including pollution, habitat destruction, and public health risks.
2. Waste Segregation Guidelines: Providing clear instructions on how to segregate different types of waste, such as organic, recyclable, and non-recyclable materials.
3. Benefits of Waste Segregation: Highlighting the advantages of segregating waste, including reduced landfill usage, conservation of resources, and promotion of recycling.
4. Recycling Techniques: Demonstrating practical methods for recycling common materials like paper, plastic, glass, and metal, and explaining the recycling process.
5. Composting: Educating participants on the benefits of composting organic waste, such as reducing methane emissions and producing nutrient-rich soil for gardening.
6. Hazardous Waste Disposal: Informing individuals about the proper disposal methods for hazardous materials like batteries, electronics, and chemicals to prevent environmental contamination.
7. Community Clean-Up Initiatives: Organizing community clean-up events to encourage active participation in keeping public spaces clean and free of litter.

In addition to educational efforts, this research introduces an innovative solution: the Smart Waste Bin. These bins are equipped with sensors and connected to a centralized monitoring system, allowing real-time monitoring of waste levels at specific points within the designated areas of the living lab. By implementing this technology, we aim to revolutionize waste management practices by enabling more efficient collection processes and optimizing resource allocation. The Smart Waste Bins provide valuable data on waste accumulation patterns, allowing for better planning and decision-making regarding waste collection schedules and routes. Furthermore, by alerting authorities when bins reach capacity, this innovation helps prevent overflow and littering, thereby maintaining cleanliness in public spaces. Through the integration of smart technology into waste management infrastructure, this research seeks to create a more sustainable and responsive system that meets the evolving needs of urban environments while promoting environmental stewardship and community well-being.

If the dimensions of the trash receptacle are as follows: height 100 cm, width 30 cm, length 20 cm, then the volume of the trash can be calculated based on the distance measured by the sensor between the lid and the trash. The formula to determine the volume is: (100 - sensor value) x Length x Width. The result is in cubic centimeters (cm^3), and if conversion to liters is necessary, it can be achieved by dividing the result by 1000.

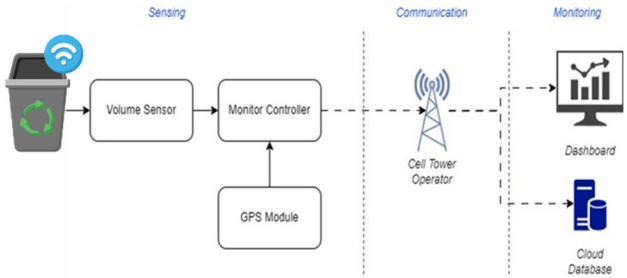

FIGURE 7. Smart waste bin system.

Smart waste bins are equipped with advanced sensors integrated into their design, enabling comprehensive monitoring of waste levels and other relevant parameters. These sensors are typically connected to a centralized platform or network, allowing for remote monitoring and management. Here are the key features and functionalities of the sensors integrated into smart waste bins:

1. Fill-Level Sensors: These sensors detect the level of waste accumulation within the bin in real-time. They can employ various technologies such as ultrasonic sensors, infrared sensors, weight sensors, or optical sensors to accurately measure the fill level of the bin.
2. Tilt Sensors: Tilt sensors detect any movement or tilting of the waste bin, which could indicate potential vandalism, tampering, or an attempt to move the bin. This information can be used to enhance security measures and prevent unauthorized access to the bin.
3. GPS and Location Tracking (Optional): Some smart waste bins may include GPS modules for location tracking, allowing authorities to monitor the exact location of each bin. This feature can aid in optimizing waste collection routes and ensuring efficient service delivery.
4. Wireless Communication: Sensors are typically equipped with wireless communication capabilities, such as Wi-Fi, cellular, or LoRaWAN, to transmit data to a central monitoring platform in real-time. This enables remote monitoring, data analysis, and timely decision-making by waste management authorities.
5. Battery or Solar Power: Smart waste bins may be powered by rechargeable batteries or solar panels, ensuring

continuous operation even in areas without access to electrical outlets.

A. HOW TO BUILD LIVING LAB

1) PLAN

In this phase, an area is identified as a pilot for the living lab. Using Garuda's smart city model, several problems arise in the living lab area. The main problem that arises concerns basic services, where the problem of energy needs and waste management is still not properly regulated, especially the waste produced by small business owners. Another problem that arises relates to parking, where transportation problems arise.

Academics as researchers in this research coordinate with the government who understands the living lab area. So a living lab area was chosen that was approved and supported by the government.

The density of the area and the diversity of the DDG area mean that the mobility of this area is quite high at this time. DDG is an area in Coblong District with an area of 7.45 km2 and a population of 110,205 people, BPS (2020). Based on the same data, it can also be seen that DDG is a very dense area with a population of 55%. Mobility in this area is also quite high. Given this, it can be said that the DDG is the center of activities and provides basic services in this area. Some services include:

- Education. There are several schools ranging from Primary school (24), Junior high School (13), High school (13), and universities (14)
- Health. There are several public health facilities such as clinics and hospitals.
- Economic Centre. Several traditional markets (2), mini markets (42), and shops (1079) are the center of residents' activities
- Culinary centers, restaurants (734), and MSMEs
- Travel. The tourist area is quite crowded
- Terminals and the number of vehicles are relatively high, especially on weekends and special days

To identify problems and solutions needed in the living lab area, we conduct forum group discussions (FGD) that involve academia, society, community, industry, and government as policyholders. the results of our activities found several problems and several alternative solutions related to economic, social, and environmental problems., we found 3 main problems that need to be improved, including

- The economy, especially in MSMEs,
- The societal problems, including mobility and security, and
- The Environmental problems, including waste and water problems. We should take this as a basis to improve the quality of life in the living lab area. Through the FGDs we also propose some alternative solutions to solve the problems and improve the quality of life in the area. But in the end, as mentioned in the previous part, we choose some innovations to solve those problems. We will discuss this in the next part of this section.

Academics as researchers are coordinating again with the government to understand the existing problems that are the current focus. Apart from that, researchers also carry out direct observations so that discussions and joint decision making with the government become stronger.

2) BUILD

Out to build innovations that implemented in the area living lab. From some innovations we choose

- Smart UMKM
  Smart MSMEs aim to increase MSME income by supporting the strengthening of the urban economy. Tin The activities carried out are the development of innovations to increase the income of MSMEs, e.g. B. Marketing projects, logistics, financial documents, etc. This innovation is also supported by digital training activities for the community, considering that there are still MSMEs that are not yet very familiar with the technology.
- Smart Mobility
  Intelligent mobility was developed to increase the safety and comfort of people on the highway. In general, the goal of smart mobility is to reduce crime and traffic violations. CCTV-based technology is being developed to monitor anomalies occurring in the community. The main objective of this technology is to manage safety and security in the mobility area.
- Smart environment
  To solve the waste problem in the DDG area, smart environment activities have been developed. The general problem with waste is that many waste spots are created because a lot of rubbish is carelessly disposed of, and the used waste bins are full and have not been taken away. Therefore, an automatic garbage can was developed that can notify the garbage collection services that the garbage is full and ready for transport.
- Citizen engagement, Education, and digital literacy
  Stakeholder engagement is carried out to ensure the involvement of various stakeholders so that the innovations developed can be built efficiently and can be implemented according to the needs of the community. more specifically engagement focus on governance related to governance and policies. for every innovation that is developed, a policy made to ensure the sustainability of the innovation. In line with stakeholder engagement, literacy is carried out so that the innovations developed can be sustainable in society. For people who don't understand, it is hoped that with literacy they understand more and gain awareness efficiently of the use of innovation. Academics can be successful in carrying out citizen engagement, education and digital literacy if they are able to strengthen coordination with the government as the liaison and with the community as the beneficiaries of this research.

So in general, every innovation that is developed in the economic, social, and environmental fields accompanied by an engagement and literacy process so that every innovation useful, effective, and sustainable to be used in improving the quality of life of the community.

3) RUN

This phase is the process of implementation of the developed innovation. The process of implementing this innovation is accompanied by interactions with relevant stakeholders. For example, for economic activities, in this case, the development and implementation of MSMEs, this activity is accompanied by a process of involving the government and related communities so that the government can support this activity through a real laboratory.

In accordance with the living lab concept, even though the scale is small and the funding is also relatively small, people in the real world really benefit from the innovations being developed. The community benefits from non-technological activities or programs, namely digital education and literacy, while the government gets new ideas and knowledge related to technological development that can improve the quality of policy making.

The findings from the practical experiences in this living lab area reveal that not all communities are willing to collaborate. The following are the obstacles encountered:

- Not all communities express a desire to participate and collaborate in waste education and waste management activities. This significantly extends the research process, as researchers must persistently engage in communication and carefully select communities within the living lab area that are open to collaboration. This undertaking is facilitated by the local government of the living lab area, which possesses an understanding of the communities with potential for collaboration.
- Not all Micro, Small, and Medium Enterprises (MSMEs) or small businesses are eager to engage in digital literacy activities aimed at enhancing their income. Many of them are accustomed to conventional buying and selling practices and are unfamiliar with the digital or online business realm, leading to reluctance to participate. The government plays a crucial role as the official forum in encouraging participation. Although some small business owners and MSMEs provided valuable assistance in identifying traders who ultimately joined the research, it is essential to emphasize that not all MSMEs took part in this research.

4) EVALUATION

The evaluation process is carried out to see the impact of the implementation of each innovation carried out in the previous phases by comparing the existing conditions and the current conditions after the implementation of the innovation in the living lab area. In other words: How can the quality of life in the neighborhood be significantly increased? In this case, the MSMEs economy has increased through a significant increase in income, fewer hospital queues, less congestion and crime in the living lab, and fewer illegal garbage dumps in the living lab. All results of this evaluation appeared on a platform that is the integrator of all living labs and discussed in the next section. The evaluation showed us how the improvement made by each innovation from the living lab. For example, how the improvement of the economy, etc. table shows us the improvement of DDG area.

VII. SYSTEM AND PROBLEM DESCRIPTION

A. SYSTEM (HOW TO INTEGRATED LIVING LAB)

In this phase, The integration of the real laboratory is done through the development of a platform that can integrate all the innovations developed in the previous phases. The architecture of the platform can be seen in the figure 8.

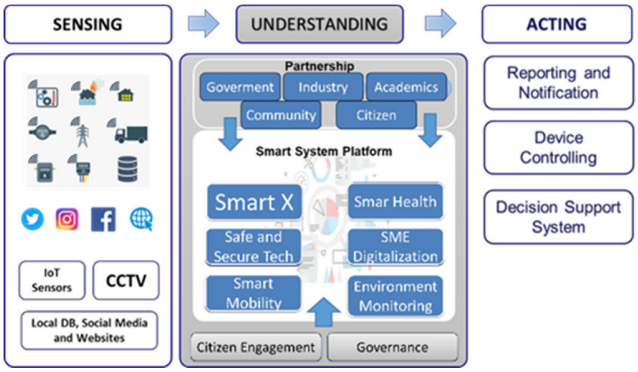

FIGURE 8. Living lab platform architecture.

Based on the picture above it can be seen how in general the living lab architecture provides an overview of how to integrate the problems that arise in the living lab area. through the sensing process, the living lab collects data either directly using IoT-based technology, as well as reports from the public, or local databases within the government. Any data that is sensed is then understood through an understanding process according to each field, whether it includes economic, social or environmental issues. Furthermore, by using technology-based innovation, this research presents actions or solutions for each problem or information produced. The following image shows how the Living Lab Platform provides solutions to environmental problems.

Figure 9 shows how the evaluation phase of environmental management features is particularly related to waste management in the living lab area. through innovation in waste management, literacy, and engagement with the government, one can see how there is a reduction in waste points in certain areas (figure a shows the waste points before the LL is implemented, and figure b after the living lab is implemented. there is a reduction of 10 waste points in this area).

The conclusion at this stage is that engagement activities with the community provide a reduction in the point of waste on the streets and increase the amount of rubbish that is absorbed between organic and inorganic. Then the data is

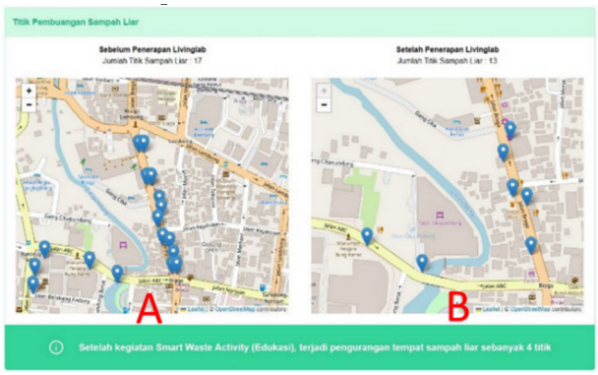

FIGURE 9. Environment dashboard for waste management.

inputted and can be monitored by the government through the Living Lab platform that this research develops

B. PROBLEM DESCRIPTION

The research introduces a groundbreaking approach to smart city development by proposing a living lab methodology as a solution to the problems faced in implementing various smart solutions for urban problems. Unlike conventional smart city projects, which often fall short in effectively addressing urban issues, this study emphasizes the integration of technological and non-technological innovations through a living lab approach. Particularly, the research focuses on the DDG (Dago, Dipatiukur, and Ganesha) area, showcasing how economic, safety, security, and environmental problems are tackled using this integrated approach. The study aims to strike a balance between technological and non-technological advancements to enhance the quality of life, taking into account Indonesia's position as a developing country with a focus on community strengthening. The innovative living lab approach, if successful, is anticipated to pave the way for future developments in both technological innovations, such as new sensors and applications, and non-technological innovations, including enhanced educational approaches.

Smart cities are cities that could use their limited resources efficiently and effectively to provide services to their city dwellers by having a smart solution and aiming to improve residents' quality of life [9]. Many cities have implemented smart cities since they emerged as an urban development concept in the early 1990s, more than 142 cities around the world have implemented smart cities [40].

LL can be a solution as it solves problems and uses actual data to solve real-world problems based on multi-stakeholder collaboration. LL as an organization to set up innovation projects that follow the principle of open user innovation and focus on the real environment to solve the problem [41].

C. SYSTEM (HOW TO INTEGRATED LIVING LAB)

In this phase, The integration of the real laboratory is done through the development of a platform that can integrate all the innovations developed in the previous phases. The architecture of the platform can be seen in the figure 8.

VIII. RESULT AND ANAYSIS

This section discuss research results from the planning process to the evaluation of each initiative carried out in the living lab area. We also discuss how the integration process from the living lab work as an integrated living lab.

The explanation in the previous sections shows us the real laboratory was successfully built to solve economic, social, and ecological problems in the DDG area. Through the Living Lab area, the economic income, especially of MSMEs, is much better controlled, so it can help MSMEs to manage and increase financial income, while in the social context, especially anomalies in the movement of people and people, multiple anomalies detected can cause traffic jams and multiple traffic violations. With the presence of CCTV bases solution, we can minimize anomalies from safety problems. While environmental management is related to the existence of a smart waste bin that can detect the level of waste, it is also possible to adjust the transport pattern for waste management, which can ultimately have an impact in terms of reducing waste points.

The process of solving problems that arise in the DDG area can be carried out not only because of the role of the existence of technology developed to solve problems as well, but also involves the role of other activities as companions, these activities are stakeholder engagement and digital literacy for the community. every innovation accompanied by a process of engagement and literacy.

IX. ECONOMIC

In the realm of economics, a paramount concern revolves around the enhancement of income for Micro, Small, and Medium Enterprises (MSMEs) by leveraging the capabilities of information technology and receiving support in digital skills. A range of applications has been meticulously crafted to cater specifically to the seamless execution of financial transactions and marketing endeavors, thereby empowering MSMEs to exercise greater control over their financial landscapes. This groundbreaking innovation is not only limited to fostering advancements in the marketing domain but extends its reach into various other economic sectors such as logistics and services, marking a pivotal shift towards comprehensive digitization.

To facilitate this transformative process, a series of specialized training sessions have been implemented, designed to equip MSMEs with the necessary skills to navigate and excel in the digital realm. As substantiated by the findings of a comprehensive study, the MSMEs in the designated Digital Development Grant (DDG) area have exhibited a discernible upswing in their digital skillsets.

Recognizing the potential impact of this technological evolution, concerted efforts are being made to ensure that MSMEs fully capitalize on these advancements. An active engagement strategy has been initiated with the government, wherein the active involvement of both MSMEs and the Ministry of Communication and Informatics is sought. This collaborative approach aims to establish a formal governance

framework, binding the threads of technology and legality, and providing a solid foundation for the seamless implementation of digital activities within the MSME sector. This not only serves as a proactive measure but also lays the groundwork for a robust and legally sanctioned environment that fosters innovation and growth in MSMEs.

FIGURE 10. Education of micro, small and medium enterprises (MSMEs) in Seminar Form.

FIGURE 11. Education for micro, small and medium enterprises (MSMEs) at sales locations.

The picture above shows the educational activities of small traders or small businesses. Education of small traders is also one of the activities carried out, namely in the economic sector. Small traders are educated to carry out buying and selling using online media and carry out professional financial management so that their business management is much better and leads to increased income.

Providing added value, we discuss the scalability of the solution and its applicability in a cultural or economic context or how the research will be sustainable, we provide an overview of how the project can continue with increased scale.

• Digital Literacy

80.19% of MSME actors in DDG mostly possess digital devices, with 44.55% of them being smartphones, and 73.26% have internet access.

• Information Competence

59.80% of MSME actors in DDG are fairly capable of searching for needed information/data (news, using search engines, locating maps, social media), and 42.17% utilize information to aid business needs (finding suppliers, observing competitors, and analyzing trends), while 63.56% are able to store, transfer, and delete information and data.

• Communication Competence

67.72% of MSME actors in DDG are capable of interacting through digital devices, and 63.56% can share information and media via digital devices, while 41.58% are fairly adept at using social media as a business marketing tool.

• Personal and Device Security Competence

59.20% of MSME actors in DDG are capable of setting passwords/PINs on digital devices, and 60.59% can disable GPS, WiFi, and 61.58% can connect to the internet, download, and install programs/applications from the internet onto devices.

• Digital Payment

34.25% of MSME actors utilize Go Pay, OVO, QRIS less frequently for operational activities because 27.52% find them less helpful for business processes and 27.92% are less interested due to not feeling the necessity of using digital payment methods.

• E-commerce Usage

25.34% of MSME actors use platforms like Tokopedia, Bukalapak, Blibli, Shopee, Lazada/other e-commerce sites less for selling their products because 15.44% find them unhelpful for business processes and 50.49% might be interested because they don't feel the necessity of using e-commerce platforms.

• Digital Delivery

33.66% of MSME actors less frequently use services like Go Food, Go Box, Grab Express, or other digital delivery methods for sending products and might be interested because they don't perceive the necessity of using digital delivery.

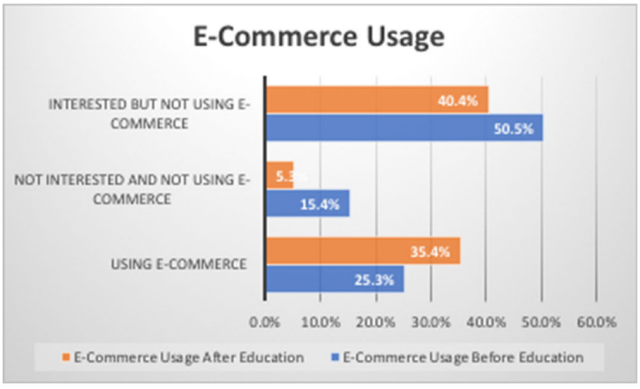

FIGURE 12. Increased use of E-Commerce after living lab research.

• Smart Economy

34.059% of MSMEs actors might find it unnecessary to use social media in business marketing and trend analysis

processes, and 20% rarely use online delivery services for business activities, while 78.41% have used digital technology in the procurement of goods, relying on manual records for business operations such as payment management, employee attendance, rarely using Ms Excel/Office for transaction records, and 20.79% utilize fewer applications for ordering goods/services.

These materials can be delivered through training sessions, workshops, seminars, or other learning programs to help improve the skills and knowledge of MSMEs in addressing challenges and opportunities in the digital business landscape.

The living lab research has conducted digital education for Micro, Small, and Medium Enterprises (MSMEs), resulting in a significant increase in the utilization of e-commerce platforms. Prior to the implementation of the digital education initiatives, the adoption rate of e-commerce among MSMEs stood at 25.3%. However, following the interventions and educational efforts facilitated by the living lab, this adoption rate saw a notable rise, reaching 35.4%.

This increase signifies a tangible impact on the MSME sector, as it demonstrates a substantial improvement in the integration of digital technologies and e-commerce practices within their operations. Through the educational programs provided by the living lab, MSMEs have been equipped with the necessary knowledge and skills to navigate and leverage e-commerce platforms effectively.

Furthermore, this shift towards a higher e-commerce utilization rate highlights the transformative potential of targeted educational interventions within the MSME ecosystem. By empowering MSMEs with digital literacy and e-commerce proficiency, the living lab research not only enhances their competitiveness in the digital marketplace but also contributes to the overall economic resilience and sustainability of the MSME sector.

In essence, the success of the living lab's digital education initiatives underscores the importance of continuous learning and adaptation in today's dynamic business landscape. By facilitating the transition towards digitalization and e-commerce integration, the living lab research plays a crucial role in fostering innovation, growth, and inclusivity within the MSME community, ultimately paving the way for a more resilient and prosperous economic future.

In addition to its impact on e-commerce adoption among MSMEs, the general digital education initiatives implemented by the living lab have also yielded significant benefits, including a notable increase in income levels. While the initial target was set at a 50% income increase, the actual improvement observed amounted to approximately 37%. Despite falling short of the predetermined goal, this increase remains substantial and underscores the effectiveness of the digital education interventions.

The 37% increase in income signifies a meaningful enhancement in the financial well-being of individuals and businesses who participated in the digital education programs. By equipping them with valuable digital skills, knowledge, and resources, the living lab has enabled them to explore new avenues for income generation, leverage online platforms more effectively, and expand their market reach.

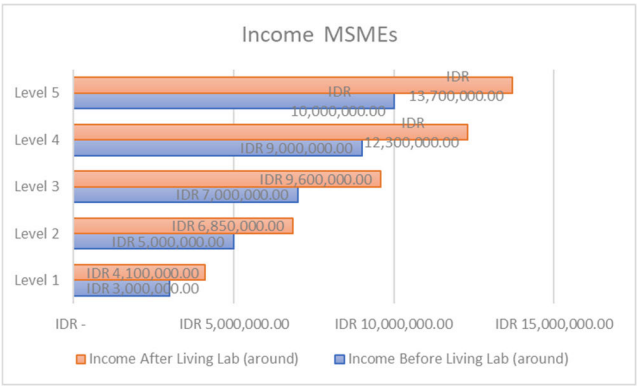

FIGURE 13. Increased income after living lab research.

Although the achieved income growth may not have reached the ambitious 50% target, it is essential to recognize the significant positive impact it has had on the beneficiaries. The enhanced income levels translate into improved livelihoods, greater economic resilience, and increased opportunities for socio-economic advancement within the community.

X. ENVIRONMENTAL

The same thing is also done in the environmental sector. The target of environmental management in the DDG area is to minimize piles of rubbish at several points in the area. This is done by developing a smart waste bin, which is an automatic waste bin technology based on IoT sensors. This trash can identifies the completeness of the waste so that it can provide automatic reports to scavengers. This facilitates waste management in a much more effective way. Another information technology-based innovation is Cleanman Hero, a trash point reporting application that appears in the DDG area. with the living lab concept which previously stated that this innovation is not just building technology, but also accompanied by engagement with the government. the government gives its role as a governance organizer through regulations related to waste management through regulations and regulations that bind waste management actors to be responsible and willing to manage waste in the living lab area. To support the success of this activity, literacy is also carried out as a basic movement in the Living Lab. literacy is carried out through a community awareness movement on the importance of waste management and its impact on the environment and the results show that there is a reduction at several points of waste reduction in the DDG area.

Figure 14 shows how the platform carries out monitoring through the Cleanman application. Officers provide input so that policy makers from the government can directly monitor the progress of their efforts in managing waste. Educational activities, seminars, door to door, and waste

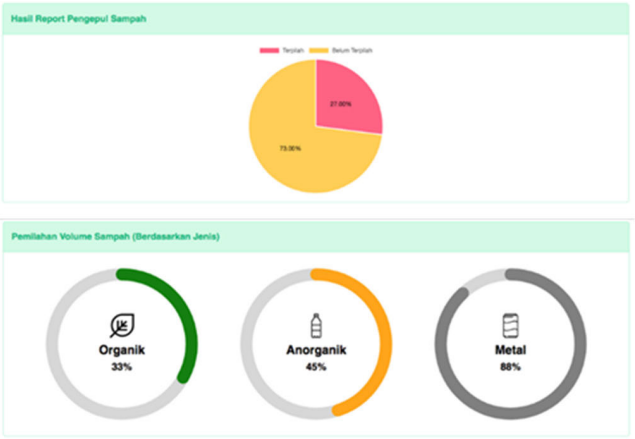

FIGURE 14. Environment dashboard for waste management.

processing training for the community in the living lab area have decreased to support an increase in the number.

The explanation above shows how all innovations as well as literacy and engagement carried out to practitioners are carried out separately from planning to execution which is carried out separately in the living lab. this is the basic concept of the living lab. but in this study, the living lab was built is an integrated living lab where every innovation, engagement, and literacy carried out is integrated into a platform called the living lab platform with the architecture shown in figure 8. where every innovation is monitored in one platform and can be used to assist stakeholders in decision making.

In addition to operational benefits, the ''smart waste bin'' innovation with sensors also supports sustainable development goals. By minimizing the number of vehicles used to transport inefficient waste, this technology helps reduce air and traffic pollution, as well as saving energy resources. Apart from that, reducing littering also has a positive impact on the cleanliness and aesthetics of the urban environment. Entire city ecosystems can experience significant quality of life improvements through the implementation of this technology, creating smarter and more sustainable cities overall.

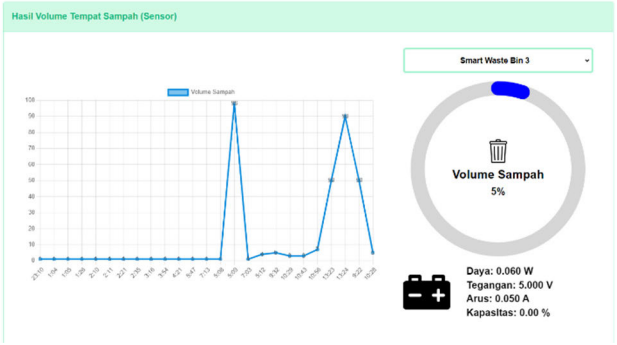

FIGURE 15. Smart waste bin display on the platform.

Smart waste bins must be supported by education to the public. With the aim that people can manage waste well and

FIGURE 16. Example Of the physical appearance of a smart waste bin.

protect the environment. Waste education/literacy in DDG Subdistrict has been carried out both in the form of door to door and seminars to the community.

The following is documentation of waste education activities for the community:

FIGURE 17. Door to door waste education activities and waste management campaigns.

As has been explained at various stages of this research, technology development coincides with the implementation of educational engagement activities. The picture above explains waste education activities for the community, starting from the basics, namely throwing waste in its place to sorting waste which ends in processing organic and inorganic waste.

The implementation of waste management education initiatives, coupled with the introduction of smart waste bins, has proven to be highly effective in addressing the issue

FIGURE 18. Education of waste management activities and organic waste processing training.

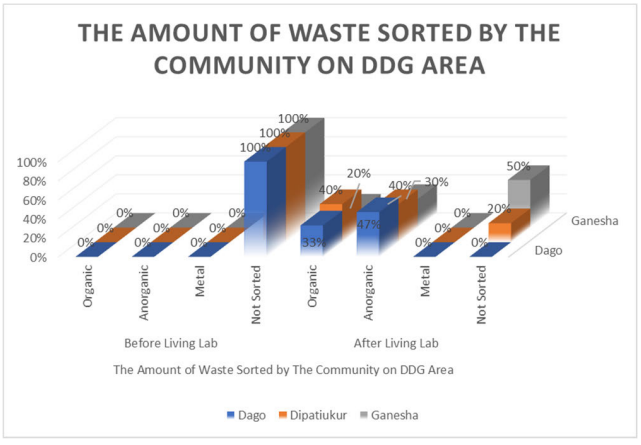

FIGURE 19. The amount of waste sorted on living lab area.

of littered areas and enhancing community participation in waste segregation within the living lab area.

Through comprehensive education campaigns on waste management practices, residents and businesses in the living lab vicinity have been empowered with the knowledge and understanding of proper waste disposal methods and the importance of recycling. This educational outreach has not only raised awareness but also instilled a sense of responsibility among community members toward maintaining cleanliness and preserving the environment.

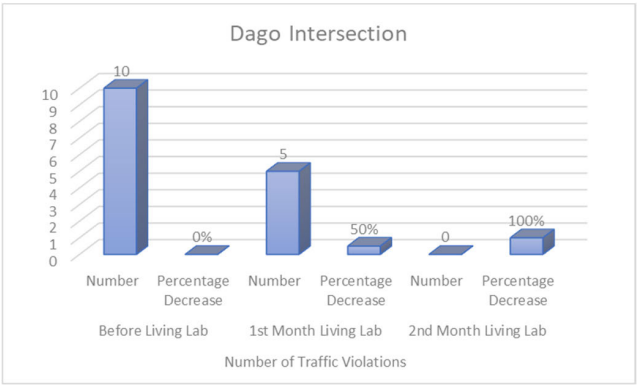

FIGURE 20. Education.

Multifaceted approach combining various strategies and interventions can be implemented:

- Enhanced Waste Management Education: Strengthen educational campaigns to raise awareness about proper waste disposal practices, emphasizing the importance of reducing littering and increasing waste sorting. Engage community members through workshops, seminars, and informational materials to instill a sense of responsibility towards waste management.
- Expansion of Smart Waste Bin Network: Increase the deployment of smart waste bins across the living lab area, strategically placing them in high-traffic areas and known rubbish points. These bins should be equipped with features such as sensors and sorting mechanisms to encourage proper waste disposal and facilitate efficient waste collection.
- Community Engagement and Participation: Foster community involvement in waste management initiatives through community clean-up events, volunteer programs, and neighborhood committees dedicated to environmental stewardship. Encourage collaboration and collective action among residents, businesses, and local authorities to address waste-related challenges effectively.
- Monitoring and Evaluation: Establish mechanisms for monitoring and evaluating the impact of interventions on rubbish point reduction and waste sorting improvement. Regular assessments of waste management metrics, such as the number of rubbish points, waste collection rates, and the proportion of sorted waste, will provide valuable insights into the effectiveness of implemented strategies.

By implementing these measures in a coordinated manner, it is possible to significantly reduce the number of rubbish points by 50-60% while simultaneously increasing the amount of waste sorted by 50-80%. This holistic approach addresses both the supply and demand sides of waste management, fostering a cleaner, healthier, and more sustainable living environment within the living lab area.

XI. SOCIAL

Furthermore, this research can see how the interactions between components in a living laboratory influence each other to provide data on how the quality of life can improve if all components interact with each other. Figure 21 shows us that this platform can detect movements that can be monitored directly by policy makers so that policy decisions can be made more quickly and precisely. In the future, we will develop sensors that can detect the movement of both people and vehicles as well as anomalies that occur such as going against the flow, careless crossings, etc. to minimize safety in mobility areas.

FIGURE 21. Sample of mobility monitoring dashboard in platform integration.

All innovations developed and implemented are supported by physical smart waste bin innovation. The "smart waste bin" innovation with sensors that can provide the condition or level of waste fullness has changed the way we manage waste in urban environments. This technology allows the use of sensors integrated in trash cans to real-time monitor the level of contents of the trash can. When the waste level reaches a certain limit, the sensor send information to the central system or to waste management officers via an internet connection. This enables proactive action in waste transportation, by optimizing waste collection routes based on priority and efficiency, reducing transportation costs and greenhouse gas emissions. Additionally, this information can be made available to the public via a mobile application or website, providing awareness to citizens about which bins still have empty capacity, reducing the likelihood of littering, and encouraging participation in recycling practices.

The implementation of video analytics and violation notification at intersections within the living lab area has yielded significant positive impacts on traffic discipline enforcement and road safety. During the first month of implementation, the use of this technology successfully reduced the number of traffic violations by up to 50% from previous levels.

Integrated with traffic monitoring systems, video analytics enables automatic detection of violations such as running red lights, crossing pedestrian lanes, or speeding. Upon detecting

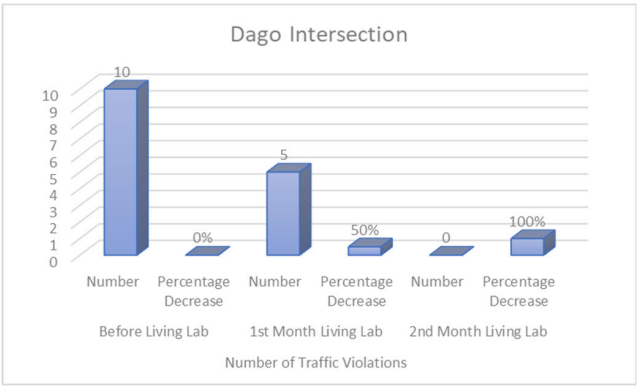

FIGURE 22. Reduction in the number of traffic violations in the implementation of video analytics.

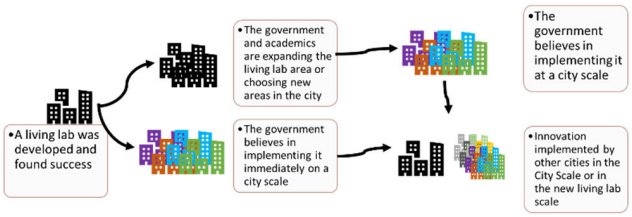

FIGURE 23. Living lab scale-up diagram.

a violation, the system automatically sends notifications to the authorities, allowing for swift and efficient law enforcement actions.

The positive impact of this technology was evident during the first month of implementation, where a notable decrease of up to 50% in the number of traffic violations occurred. This indicates that the video analytics and violation notification system are effective in providing a deterrent effect and increasing drivers' awareness of traffic rules.

Furthermore, in the second month post-implementation, no violations were reported at the intersections. This success marks the adoption of a better safety culture among road users and the effectiveness of the system in delivering long-term effects on driver behavior.

XII. DISCUSSION

First, after all the live laboratory studies have been carried out. The results of the evaluation were carried out and the academics who conducted this research submitted the results of their evaluation to the government. Academics can recommend expanding the living lab area from the existing living lab point, or recommend a new living lab area, or recommend implementation on a city scale. The decision depends on the government.

The important point is the results of the overall evaluation. In this research, the important points that must be underlined are:

1) The combination of real activities in society such as education or literacy with technological development must be carried out together in one package and

supervised simultaneously. one and the other are mutually connected.

2) Not all areas can be used as living lab areas, depending on several factors:
   - Areas where the community is willing to join in to make the living lab a success, this takes a very long time because researchers have to make changes to their actions when the community is inconsistent in their involvement.
   - The government recommends these areas as part of government programs
   - There is no total rejection from the community in the living lab area
3) Not all innovations can be applied in a living lab depending on several factors:
   - The field of innovation is a field that in real conditions has problems and is of concern to the government
   - The government gives permission for innovation to be implemented in the living lab area
   - Financial innovation must be met by implementers, in this research, academics
4) Innovations developed in this Living Lab research still need to be increased features. In fact, every time the living lab is expanded after the previous livinglab area, an increase in features must continue to be improved following the needs of problems in the real world. In this study, there are several things that need to be developed:
   - In the social field, it is not only smart mobility to automatically detect vehicle movements, but in the future it will be developed to detect the anomaly of human movement.
   - In the environmental field, it is necessary to strengthen public education in sorting organic and inorganic waste
   - In the field of the environment too, waste monitoring is very dependent on waste updates by garbage officers, in the future it must be considered how the waste can be updated automatically, either through sensors or video analit
   - In the economic field, education to small traders for the use of online media must continue to be improved. Then the additional features for the ease of shipping from producers to small traders can also be developed
   - and other development and improvement in accordance with the next living lab area
5) In order to expand the living lab area or conduct new research in a different living lab area, academics must secure adequate funding. Despite the funding being relatively small compared to city-scale policies, academics, in this case, do not receive routine funding similar to that of the government. Therefore, the sustainability of this research necessitates collaboration between academics and financial support, which may come from the private sector, private companies, or the government.

TABLE 1. The evaluation and success indicators of the DDG are.

Domain	Innovation Proposed in Living Lab	Target and Currently	
		Target Improvement	Currently
Smart Economy	E-Commerce Usage and Income improvement	Improve by 50%	E-Commerce Usage 25% and Income: around 37%
Smart Society	Video analytic for safe and secure and mobility	Down to 28% Incident for safe and secure	0 trafic violation during implementation of video analytics and notification alarms
Smart Environment	Smart Waste Bin and Smart Waste Education to support waste management	Improve Quality 65%	Decrease 50-60% rubbish point and increase 50-80% the amount of waste sorted

The provided table illustrates the domains and corresponding innovations proposed within the Living Lab framework, along with their targeted improvements and current status. In the Smart Economy domain, the focus is on enhancing E-Commerce usage and income generation. While the initial target aimed for a 50% improvement in both areas, the current status reflects a commendable increase in E-Commerce usage by 25%, and an approximate 37% rise in income. This suggests a substantial positive impact on economic activities within the community, although slightly below the set target.

Moving to the Smart Society domain, the proposed innovation involves the implementation of video analytics to enhance safety and mobility. The target improvement aimed to decrease incidents for safe and secure mobility by 28%. However, the current status indicates a remarkable achievement, with zero traffic violations reported during the implementation of video analytics and notification alarms. This highlights the effectiveness of the innovation in promoting safer and more secure mobility within the Living Lab area.

In the Smart Environment domain, the innovation focuses on utilizing Smart Waste Bins and implementing Smart Waste Education to support waste management practices. The target improvement here was to enhance waste management quality by 65%. The current status reveals promising results, with a notable decrease of 50-60% in rubbish points and a significant increase of 50-80% in the amount of waste sorted. This indicates a positive shift towards more efficient waste

management practices, contributing to a cleaner and healthier environment within the Living Lab.

Overall, the table showcases the diverse range of innovations being implemented within the Living Lab framework, each aimed at addressing specific challenges and fostering sustainable development. While some domains may have slightly missed their target improvements, the overall progress reflects significant advancements towards creating a smarter, more resilient, and environmentally friendly community.

These innovations not only improve the quality of life for residents but also serve as valuable learning experiences for future urban development initiatives. The important point is the real impact, even though it is small. The results of collaboration between academics, government and society have a direct impact. This research shows that the role of technology is very significant in improving the quality of life of city residents, what can be done in a package with solid educational activities for the people and communities who participate in implementing the innovations that have been taught.

This research has an immediate impact even though there are limitations in the living lab concept. These limitations are that the number of people who receive the benefits of this program is very small compared to the city community as a whole and the innovations developed are very few compared to other city problem areas that have not been touched by innovation in this living lab.

XIII. CONCLUSION

The construction of a living lab in the DDG area which aims to improve the quality of life in a limited area has been successfully carried out through 4 main stages, namely plan, build, run and evaluate. Developing innovation, involvement and literacy of all related parties is the key to achieving increased digitalization of MSMEs, increased safety in the mobility sector, and the effectiveness of waste-based environmental management in the DDG sector as an answer to the first research question. Meanwhile, the second question related to integration has succeeded in developing an integration platform that can integrate data related to economic, social and environmental issues from DDG's Living Lab. This research has answered that the success of a living lab in improving the quality of people's lives must combine technological and non-technological approaches. Platform (technology) development is to become an enabler for non-technology policies, one of which is educational programs for the community as has been carried out in this research.

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