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Supporting the National Innovation System: The Role of Participatory Mapping Activity with OpenStreetMap OSM

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Abstract—**Nowadays, there has been growing recognition of the vital links between Innovation, collaborative intelligence, and social participation. The interaction between stakeholders is a significant driver for the flow of information and innovation in technology via open data and open-source platforms. At the national level, the National Innovation System (NIS) must be implemented to support and ensure this flow based on Regional Innovation System (RIS). Open Spatial Data Infrastructure SDI plays a central role in enabling web-based services. For instance, the open spatial data platforms supply base maps, which allow spatial analysis, data visualization, and a large matrix of applications for many use cases. In return, ease Sustainable Growth Strategy SGS implementation and enabling of NIS. This paper studies the importance of collaborative platforms for Participatory Mapping Activity PMA and Volunteered Geo-Information VGI, considering the base map from OpenStreetMap OSM as a part of Spatial Data Infrastructure SDI to support national economic development and creation of economic value added with NIS.**

***Key Words*— National Innovation System NIS, Regional Innovation System RIS, PMA, OpenStreetMap.**

I. INTRODUCTION

THE innovation is the tie that links the academia and industry with the society. Innovation could play a significant role in the sustainable development and growth of economic systems [1]. The economic growth and development are related to the ability to exploit and optimizing the use of resources and competencies, which found in different locations and widespread on territorials. The interest in the innovative activities within specific territorial areas led to the development of several concepts for the implementation, exploitation, and the processing of Regional and National Innovation Systems. This process is driven by various factors, for instance: geopolitical concerns, strategies and policies of sustainable development, environmental impacts, local and regional competitiveness, business opportunities, economic dynamism and stability, social awareness and collective intelligence, knowledge accessibility, and information sharing [1-3]. The national innovation system supplies a holistic model for the innovation process and emphasizes the role of the interaction of political, institutional, and social factors. Based on the geographic approach, Participatory Mapping Activity PMA could be considered as a socio-technical activity conducted by volunteers and contributors. That aims to digitalize cities and urban areas. Therefore, PMA contributes directly and primarily to the building of NIS through an RIS. Where it could enable spatial data collection, thence allowing the Spatio-temporal analysis, which is vital for the improvement of social, economic, and environmental systems from regional to national dimension. Collective intelligence provides a mechanism for combining resources and competencies. This paper consists of three main parts and tackles topics as following: 1) Introduction 2) the emergence of the National & Regional Innovation System. 3) explores the concepts of PMA and PGIS. 4) highlights the Geographical Information System GIS and its usage to develop a regional economy based on a platform that identifies all resources and competencies in order to combine it to create a value-added through Synergy. 5) A proposition to combine GIS analysis and collective intelligence with supporting innovation. The last section focusses on the case study: PMA on OSM is supporting the RIS, NIS, and PSS.

II. THE NATIONAL & REGIONAL INNOVATION SYSTEMS: A THEORETICAL ISSUES

Both the National & Regional Innovation Systems are related to the flow and sharing of knowledge and access to data and information. Sustainable development strategies are adopting regional policies to increase the regional potential of growth and development based on innovation and regional competitiveness. Poles of excellence and clusters could bring together academia and industry to develop the innovation process. From the spatial point of view, understanding the space and time makes location vital for policymakers. Where the massive location data allows the Spatio-temporal analysis for better development strategies and structure of innovation systems. Furthermore, it provides a source of information about the interaction of institutional, human, natural, and physical systems. Therefore, the innovation environment is influenced

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mainly by the inter-relations of actors, technology performance, policies, poles of excellence, clusters of innovative businesses at the regional and national levels [4][5].

A. The National Innovation System (NIS)

The term National Innovation System has been used for the first time by Freeman C. 1982 UK, thence, Lundvall B.-A in 1985 in Denmark has presented and developed a closer approach. The innovation process must be developed within the logic of systematic improvement [6]. The flow of knowledge, technology, and information plays a significant role in the process of innovation and supports the interaction of stakeholders. The national innovation system provides a better understanding of policymaking and helps to identify leverage points for enhancing innovative performance and overall competitiveness [4]. The regional innovation system is essential for an effective national innovation system, as it can support a comprehensive matrix of sectoral innovation systems. However, certain conceptual elements that support both regional and national innovation systems must be analyzed in order to identify and understand how systems support each other [7]. Innovation is fundamental to the competitiveness of firms, regions, and nations; it is a learning process that could be conceptualized as a non-linear, complex, and interactive [8].
A literature review has been conducted to understand the meaning of the National Innovation System of NIS; Table I shows definitions developed by academic pioneers of NIS and some related keywords.

Table I: Definitions of NIS developed by principal academic pioneers

Authors	Definitions of National Innovation System	Keywords
Freeman, 1987	The flow of new technology due to effective interaction by public and private stakeholders and actors	Interactions, Network, New technologies.
Lundvall, 1992	The relationships and interactions for the production and sharing of new and economically useful knowledge	Interaction, knowledge, Borders
Nelson, 1993	the determination of the innovative performance of national firms by a set of institutions interacting effectively	Interactions, Innovative performance, National firms
Patel and Pavitt, 1994	the determination of the rate and direction of technological learning by the national institution's incentive structures and competencies. or the change generating volume and composition of activities in the country	Competencies, Technological learning, Country
Metcalfe, 1995	the knowledge skills, and artifacts created, transferred, and stored by a system of interconnected institutions that define new technologies.	Interconnected , skills& artifacts, new technology
Lundvall et al., 2009	NIS tool is used to determine which alternative of the institutional arrangement supports the strong dynamic performance (national/regional) of the economy or a sector.	Tool, Dynamic performance, Economy

Two dimensions have been identified through the analysis of NIS concept definitions, Table II presents categories classification for the system conceptualization and answering the “What” and “Why” questions.

Table II: National Innovation System Conceptualizations

What vs. Resources	Why vs. Objectifs
Interactions Network Knowledge (share, Transfert) Borders (special) Institutions (publis & Privats) Competencies, Skills	Diffuse New Technology Innovative Performance Dynamic Performance Technological learning

The national innovation system is defined as a set of socio-economic interactions among actors that integrated within a collaborative approach and located in a specific geographic area and mobilizing all resources and available competencies to promote, favorite and maintain the development of the economic dynamism based on the sharing knowledge, learning, innovation, and technology. The National economic performance is related to the regional economic performances in a nation [7]. Therefore, NIS will be easily formed and implemented in terms of effective RISs. The NIS can be illustrated as a matrix of regional and sectoral innovation systems. The concept of NIS can be significantly more analyzed, projected, or dropped at different levels by keeping the same conceptual and modeling parameters such as clusters that focus on the interactions between particular types of firms and sectors, sub-regional, regional, national and international, where subdivisions are related to:

- Geographical issues, resources localization, and populations.
- Governance and policies.

B. The Regional Innovation System (RIS)

Michael Porter has observed that the contemporary interest in regional clusters and regionalization trend might be influenced by the discontinuity in recent economic history. In industrialized countries, Fordism to the poet-Fordism transition process is the dominant form of production and Causes various significant consequences for the organization and localization of industrial activity, and regional development processes and regional policies. [9-11]. **S**ince the early 1990s, more attention has been paid to the concept of the Regional Innovation System from policymakers, academia, and industry [12]. Where a promising analytical framework for the advance understanding of the innovation process in the regional economy has been developed [13]. The set of resources that are located in a specific individual place and supports certain economic activity could enable the Regionalization [9][13]. Over the last decades, the significant growth of regional cluster and innovation systems considered as the principal empirical indicator of the trend towards regionalization. The regional cluster concept could be defined as a concentration of interdependent firms in a specified geographical area in co-operating with surrounding actors from academia, industry, and regional institutions [9]. For better understanding, some standard features for the success of Regional Innovation Systems have been distinguished:

- **Economic activities** (high GDP, export, a great representation of businesses, the presence of knowledge-intensive industries, skilled workers).
- **Research activities** (private R&D expenditures, the emergence of new technologies in the region).
- **Research infrastructure** (robust and diversified R&D institutions meeting the requirements of businesses).
- **Policy** (political awareness, relevant objectives, appropriate strategy).
- **Social networks** (interactions between entities, relations between businesses and research representatives, the cooperation of the businesses) [5].

The difference between RIS & NIS concepts is appropriate and useful in particular when tackling the implications of policy implementation. Therefore, the regional clusters are manifest as a spontaneous phenomenon in a geographic concentration of firms that are often developed through local spinoffs and entrepreneurial activity [9]. On the other hand, RISs, have a more explicit policy, planned and systemic character. Therefore, the transition from a cluster to an innovation system requires a strengthening of a region's institutional infrastructure and more knowledge organizations. Both regional and national levels are involved in innovation co-operation, thence, The RIS could be considered as a tool to create a supporting system of innovation at the national scale.
In the globalizing economy, it is challenging for RISs on their own to remain competitive. At the regional level, production systems appear to be more critical for the innovation system. Thus, local firms must have access to both national and supranational innovation systems and expand beyond their boundaries through a process of economic integration and globalization [14]. Initially, the RSI approach was developed by scholars of the geographic economy [2] while they were trying to understand the unique role of institutions and organizations in the regional concentration of innovative activities [14]. Moreover, the RIS is theoretically multidimensional and bringing together economy, management, and geography in a sustainable vision and sophisticated approach.

III. THE PMA AS A TOOL OF DIGITAL TRANSFORMATION THROUGH PGIS

PMA is a bottom-up approach that allows the masses to create maps for all, in contrast to the traditional top-down approach [15], relying on contributors to supply power and resources for the creation of maps that will benefit the masses either directly or indirectly. Most PMA projects can be categorized under six broad themes [16], based upon their purpose:

- articulate and communicate spatial knowledge to outsiders.
- Recording and archiving local knowledge.
- Land-use planning and resource management.
- Advocate for change.
- Increase capacity within communities.
- Address resource-related conflict.

The PMA is considered as a pillar for a Participatory Geographical Information System PGIS [17]. The main goal of PGIS is to include participatory information in the decision-making process [18] and to support the use of local knowledge in research, communicative planning practices, and long-span development processes [19]. However, the focus of PGIS is to combine resident perceptions with spatial information so that they can be viewed side by side with equal importance. [17][19-21]. The PGIS challenges are usually community empowerment, social justice, and inclusion of local knowledge in the discussion of development decisions. Challenges overcome related to the quality of government decision making. Among decision making, urban planning as a process requiring communities' participation and interaction with government and public authority for better communication and to improve performance. For instance, the PGIS could potentially contribute to smooth the planning and design processes and reduce the number of conflicts, promotes adaptation to continuously changing societal conditions, strengthen recognition of the differing values of various actors, support learning and knowledge building, and, finally, help to achieve tangible regeneration outcomes [22]. The PMA embodies one of the forms of collective activities to provide digital tools for the decision-making process. Thence, enhancing the Planning Support Systems PSS that coherent with the lifecycle thinking. During such activities around PGIS, collective intelligence appears through the interaction of the community of contributors on the digital platforms and networks of Volunteered Geo-Information VGI with government institutions to provide Spatial Data Infrastructure SDI that supports wide matrix of applications and use cases for the implementation of sustainable development strategies and policies and enabling the digital transformation and smart city concept. Figure 1: represents the PGIS process and the interaction of community and government [23].

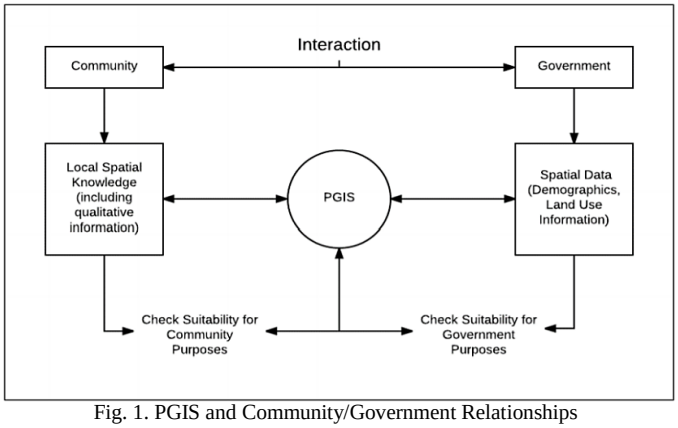

Fig. 1. PGIS and Community/Government Relationships

IV. COLLECTIVE INTELLIGENCE: CREATE VALUE THROUGH SYNERGY

User participation, online communities, social networking, mass collaboration, and open innovation have become new tools to shape the collective intelligence and social capital at the service of the society to increase its performance and to develop its creative abilities [24]. Collective Intelligence is a

factor of success for modern societies based on the development and sharing of information and knowledge. In return, society becomes more and more knowledge-dependent; the collective social ability could be a driving force for innovation [25]. From an empirical point of view, understanding the mechanism of value creation needs the following question to be answered: How could collective intelligence contribute to the innovation systems through the PGIS & VGI, PMA, and add value to the digital transformation process, for instance? In order to answer this question, more clarification of the collective intelligence concept has to be presented. Collective Intelligence generally defined as the intellectual cooperation capacity of the human communities and describes their abilities for creation, innovation, and invention [26]. Collective Intelligence can also be viewed as a set of behaviors that have been emerged from different networks and dynamic involved people, technical devices, and messages (composed of symbols) in order to represent, understand and improve this network or application [27]. However, to understand the mechanisms of value creation, the flowing sub-networks composing collective intelligence have to be considered:

- The network of people.
- The network of physical and technical infrastructures.
- The network of recorded documents or archives.
- The network of relationships between people and ideas.

To distinguish the types of networks, the following table visualizing the characteristics and the conditions of the creation of the value, Table III [27].

Table III: Types of networks

Collective Intelligence Sub-Networks	Caractéristiques	Value
A network of people KS Homogeneous relationships between beings	is represented in the model by interconnected social roles. This network of people constitutes the social capital (KS) of the community	KS the value depends on the quantity and quality of social ties, the overall expression of which is the climate of trust that reigns in the community.
A network of physical and technical infrastructures KT Homogeneous relationships between things	includes not only cyberspace and communication media but also urban equipment, transport networks, industrial infrastructure, etc. This material network constitutes the technical capital (KT) of the community,	KT, the value also depends on the quality and the quantity of the links and which is manifested by its usefulness and its effectiveness.
A network of recorded documents, or archives KC Homogeneous relationships between signs	brings together all of the messages accessible to the community, whether it be media content, that of museums and libraries, or that of the Great Hypertext of the Web. This semiotic network constitutes the cultural capital (KC) of the community.	KC, the value, again, depends on the quantity and quality of the links between documents and which is expressed by the consistency of the accessible media library.
A network of relationships between people and ideas KI Heterogeneous relationships by nature	ultimately forms the intellectual capital (KI) of a community. It is he who represents the symbiotic relationship of humans and ideas, the abstract "place" where ideas are conceived, reproduced, maintained, and selected.	KI produces and reproduces the three preceding capitals while these constitute the conditions of the possibility of its fertility.

Based on this sub-process, an integrated model could be developed, and that combines PGIS and Collective intelligence to create a favorable environment for creativity and innovation in a sustainable economic growth view.

V. A PROPOSITION TO COMBINE PGIS ANALYSIS AND COLLECTIVE INTELLIGENCE WITH SUPPORTING INNOVATION

The Global Positing System GPS could provide the exact latitudinal and longitudinal coordinates for a given point or location according to various datums and Geographical Coordinates System GCS. The georeferencing process allows building and creating precise maps. The Geographic Information System GIS is allowing the storage, analyzing, and overlying of many layers of the geospatial dataset and geographical information and define them to a specific GCS. That facilitate and ensure the spatial information management within the area of interest or specific geographical region [15]. In addition to the visualization and exchange of data models. PGIS could be experienced through the use of OpenStreetMap OSM, where contributors are editing collectively and volunteering the spatial data on the mapping platform to enter and update vector data (point, line, polygons) with their related attributes, the semantics of objects. Wince map is edited and updated; it could be downloaded freely according to the open data license and user agreement. For instance, Users can exploit the dataset and the OSM base map for GIS application and engineering tools. Recently, OSM is widely used for humanitarian tasks, Urban Planning UP, conception, and modeling activities. The OSM base map could be updated, modified and reloaded back to the OSM platform and displayed for the users within a smooth process of collaborative mapping activity in the form of wiki-map project that reflects the idea or the concept of knowledge sharing via Wikipedia where the content is developed by contributors [15]. Therefore, a combination of GIS, OSM, and PMA is proposed to support the National Innovation System based on the Regional Innovation system. It is essential to identify all local resources and competencies in order to develop a local economy approach; table IV explains how for each region of the national territory, all the resources and skills can be mapped according to each sector of socio-economic activity and not only purely economic. Thus, based on this matrix which combines the geographical dimension and the sector dimension of socio-economic activities seems to be relevant to define a collaborative approach by the participation of all the actors (public institutions, academia, industry, civil society, and citizens). Allowing the implementation of NIS that could support the Sustainable Growth Strategies SGS.

Table IV: R:Resources, C:Competencies, GIS:Geographical Information System

	Sector A	Sector B	Sector C	Sector D	Sector E
Region 1	$R_{a1}C_{a1}$ (GIS)				
Region 2		$R_{b2}C_{b2}$ (GIS)			
Region 3			$R_{c3}C_{c3}$ (GIS)		
Region 4				$R_{d4}C_{d4}$ (GIS)	$R_{e4}C_{e4}$ (GIS)

Ra1Ca1 (GIS)	Natural Resources	Resilient Sustainable	Ecosystem Collective Intelligence Spatial Data Infrastructure Decision-making Finance Culture,Traditions Environment	RIS	Territorial Regional Development	NIS
	Human Demographic evolution	Skills Competencies Knowledge, Experience Know-how				

Based on a territorial approach, building a National Innovation System requires the analysis of all the sub-systems at the regional or sub-national level. The aim of the analysis at the regional level is to identify all of the resources and skills available in a given geographic area. Since development is a place or location related and its dynamism is linked to the time factor, PGIS provides the tools of Spatio-temporal analysis, in return enables the decision-making process and enhancing the PSS, the sustainable development is linked directly to space and time parameters, which confirms the thesis of IBN Khaldun as specified by many authors who analyze the life cycle of a civilization.

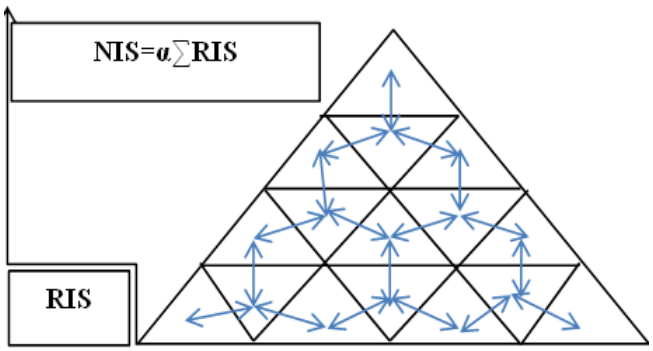

Fig. 2. A Bottom-Up Approach of National Innovation System: an explication based on interactions of sub-systems and information transfer (α refers to the intensity of interactions between regions and the central government in terms of Transfer and sharing of knowledge and information)

Developing sustainable economic growth is primarily related to the local area as a central unit that reflects the community's needs. Therefore, to build a national innovation system in an integrated approach, the analysis method must focus on the geographical issue. The bottom-up technique permits a real collaboration of all stakeholders to make a transparent decision. However, the interaction between local, regional, and communities with governments improves the optimization of resources and competencies to achieve objectives. Mainly, the building of Geographical Information System GIS through using PMA is an efficiency method to create a platform mutualizing competencies and resources in order to invest in collaborative projects. As a result of this theoretical and analytical work, a model that can be tested through a case study has been developed, Figure 3.

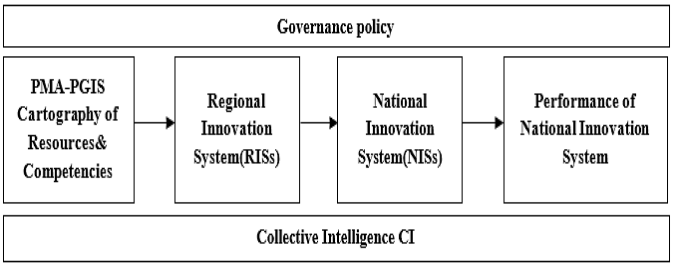

Fig. 3. Performance of National Innovation System through Bottom-up approach

VI. Case Study: PMA on OSM is supporting the RIS, NIS, and PSS

The reconstruction of the 3D City Model is essential for city management, where it is considered as a city knowledge and information sharing tool. This functionality supports the collaboration and interaction of city actors to enhances communication between stakeholders. Corporation and knowledge sharing based on CI are the foremost common points with the RIS that creates and supports the NIS in return. The sophisticated abilities of the 3D City Models for visualization making complex physical systems and infrastructure clear and easy to understand because our real world is in 3D. Enabling the City Information Modeling CIM based on 3D City Model and digital twins could contribute to the implementation of smart city concepts by supporting the NIS and connect citizens to their city. The reconstruction of the 3D City Model employs many techniques through various phases. For instance, during the phase of data collection, various techniques could be used, such as Light Detection and Ranging LiDAR, Remote Sensing RS, and VGI. The VGI is conducted through PMA using open data platforms for PGIS, driven by CI and socio-technical awareness. Having an efficient digital toll for the PSS facilitates the implementation of sustainable development. From a technical point of view, the RIS, NIS, and PSS are influenced by CI and digital transformation. This case of study presents the 3D City Model of the project of SUNRISE Smart City Project site, which is a simulator and large-scale demonstrator of the smart city [28][29]. In this project, the PGIS and PMA are providing the base map from OSM platform. The OSM concept is built based on the CI and the awareness about the importance of mapping and digitalizing the real word with PGIS. The base map from OSM is used in this project for mapping and localizing sensors that connected to buildings and different networks. Figure 4 shows the topographic map of the University of Lille with buildings and infrastructure footprint stored with their associated attributes and semantics on the platform of OSM. The base map has been used to extract city features and extrude 3 D City objects to create the 3D City Model of the University of Lille, figure 5.

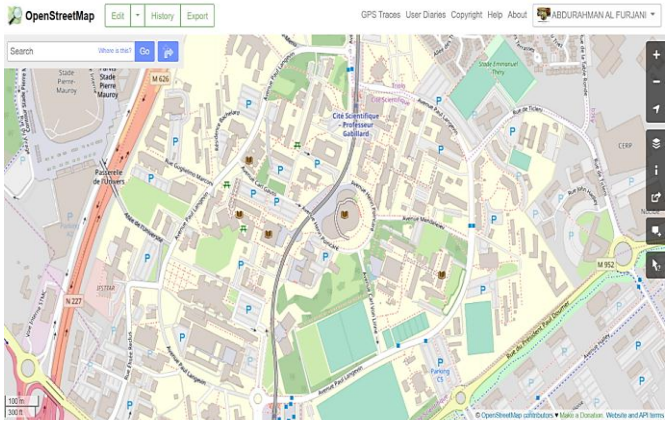

Figure 4: OSM base map for PGIS for the campus of the University of Lille


Fig. 5. 3D City Model of the campus of the University of Lille

Figure 5 presents the 3D City Model extruded based on PGIS of OSM with Lumion Pro for students version. This model provides an innovative environment to support the ecosystem and improve the PSS, RIS, and NIS.

VII. CONCLUSION

Building a National Innovation System NIS is a process that started in the local area as a central unit of national economic growth. A sub-national economic analysis constitutes a critical issue to optimize and mobilize resources and competencies to develop and create a regional dynamic innovation ecosystem. Therefore, digitalization and ICT infrastructure offer for all socio-economic actors the opportunities to collaborate by using a set of new methods and tools in the scale of cities. Using PGIS and OSM facilitate the cartography of all resources and competencies related to the economic sector. This visualization of information and data in a central platform from regional to national levels improves the quality of decision-making to establish a bottom-up approach of national innovation system. The performance of NIS must be support by collective intelligence and efficient governance and policy from the local to national scale.

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