A Novel Application of City Information Modelling: Filling the Gap in the Data Through Better Citizens' Engagement. Insights from Al Baqa', Jordan

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Abstract

City Information Modelling (CIM) is a new approach which merges existing digital technologies for urban and building management. Its application is still in its infancy, as well as its potential has been not yet fully exploited. This paper presents some preliminary findings from a novel application of CIM to a pilot case study providing fresh insights on how CIM technologies can be applied in urban areas where inconsistency of data may challenge the implementation of digital technologies. The novelty of the method stems from a mixed methodology, which integrates knowledge and technical expertise on CIM and social science thus providing a basis for building community resilience. The case of Al Baqa' has been chosen, as paradigmatic example of a challenging urban context, as it was originally a Palestinian refugees' camp, and evolved over time into a dense development of mainly two-story concrete buildings. High population density in the area impacts on the environment in terms of pollution, shortage of services, water sewage efficiency, and waste management. Refugees have been living in Al Baqa'a since 1967 facing daily challenges from different angles: political, because of the precarious acknowledgement of their rights as citizens; economic, for the settlement offers limited opportunities to grow; physical, as Baqa'a residents are plagued by a variety of issues, including underperforming water sewage system, lack of ventilation and daylight in the houses, poor waste management. In such context, the pilot project aims at developing a CIM prototype, merging in one platform a variety of data, including mapping of the water sewage system, 3D views of the buildings, and qualitative data collected from residents, in an attempt to combine data from different sources and actors and explore the potential of CIM in overcoming one of the major environmental challenges, e.g. water management. Further studies may apply the same methodology to different contexts and or different sectors, thus allowing for a better understanding of potential benefits of CIM in terms of enhanced community resilience.

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A. Rubbo et al. (eds.), *Design for Resilient Communities*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-031-36640-6_28

Keywords

Water management · Informal settlements · TLS · GPR · Community resilience

28.1 City Information Modelling and Enhanced Integrated Planning

CIM is a relatively new digital technology that merges together data normally managed through Geographic Information Systems, e.g. topological data layers typically pertaining to the urban planning and management domain such as flooding risk, topography, geographical landmarks, urban fabric characteristics and features, with data normally managed through Building Information Modelling, e.g. databases linked to a 3D digital model of a building including its structural and mechanical engineering subsystems, materials of construction and related thermal, structural, fire resistance specifications, geometric dimensions, and any other data that can be useful to manage the building. CIM platforms hold the potential to integrate massive amount of data thus enabling in-depth analysis and more accurate simulations, supporting better planning and urban management. In urban contexts where availability of digital technologies is widespread and rooted in local and regional governments institutional frameworks, this is relatively easier. However, in context challenged by scarcity of resources, this might be more difficult. Some examples show potential of digital technologies to support the health and social well-being of populations affected by humanitarian crises resides in their use to better understand their needs, thus facilitating humanitarian response efforts and engaging affected populations in the response (Mesmar et al. 2016). Although where people can easily access digital technologies, then Information and Communication Technologies (ICTs) enable communities to access information and other services, whilst marginalised communities do not have the opportunity to use ICTs, as they lack access to information relevant to their lives.

Digital technologies can be powerful tools in support of participatory design and provide architects and planners with an opportunity for fine tuning the design of cities to their citizens' aspirations, thus unleashing the potential embedded in the community vision and developing more sustainable urban strategies, including more valuable and richer public realm and community spaces (Horgan and Dimitrijević 2018). It is therefore imperative that a better and more widespread use of such technologies is pursued in those settlement, which most face socio-economic and environmental problems. These settlements present the greatest challenges to sustainable human development and equity, safety, environmental quality and resilience, central aspects of the UN 2030 New Urban Agenda.

This latter promotes making cities and human settlements inclusive, safe, resilient, and sustainable in combination with technological innovation applied to infrastructure, by encouraging the field of research on the interaction of architecture, cities, and digital technologies. An additional emphasis on the broader challenge of informal settlements and marginalised societies is demonstrated through three explicit targets for inclusive cities: target 11.1 in the Sustainable Development Goals (SDGS), which ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums; target 11.5: ensures to significantly reduce the number of deaths and the number of people affected by focusing on the protection of the poor and people in vulnerable situations; and target 11.6 seeks to reduce the adverse per capita environmental impact of cities, with particular attention to air quality and the management of municipal and other waste.

In this framework, CIM technologies as enriched by the socio-economic perspective offered by a participatory design approach channelled through digital technologies, can be really ground breaking as they hold the potential to bridge the gap between experts and citizens knowledge thus enabling better understanding and management of urban issues. According to Souza and Bueno (2022), who conducted a comprehensive and systematic literature review on the state of art on CIM, still ambiguity and lack of clarity on both the concept and the potential of this technology persists. A major challenge to a full implementation of CIM lies in the political difficulty embedded in the data governance process, which is a common issue affecting effective planning. Multi-agents' platforms are therefore challenged by the availability of suitable intuitional frameworks endorsing (or enforcing) their implementation. Embedding the tacit knowledge engrained in the communities in such platforms, adds another layer of complexity. However, the combination of formal and structural knowledge hold (and sometime retained and not shared) by institutional actors in different public and private sectors and tacit and unstructured knowledge that lies with the communities, is what would make a substantial shift towards a reliable and constantly updated geographical dataset, with a high degree of granularity.

This assumption was the main driver beyond setting the goal of the prototype: to develop and trial through a prototype platform a new digital platform aimed including a marginalised community into the urban management process. The case study of Baqa'a was chosen as it shows a high level of socio-economic complexity and is challenged by a variety of environmental issues. The project started by engaging with local experts in order to identify the major challenge for the Baqa'a community, suggesting that the focus should have been water management. Subsequently, a systematic survey of a pilot area has been conducted, including documenting the urban fabric and its residents' view on this topic, in combination with data on water and sewerage system management with the final goal of supporting more sustainable urban management and strategies in the al Baqa'a refugee's camp.

As information and communication technologies (ICT) become predominant, the architects and planners have to rethink the rules of communication between the citizen and the physical urban space in order to be adapted to the period in which people live, with the resources available to them. ICTs, mobiles, apps, and digital technologies are tools that enable slum dwellers and their young people to have greater control over their lives (Ghorbanbakhsh and Paio 2021). This suggested to enrich the BIM Platform with a related app, users friendly and open to the residents, to upload data in real-time thanks to a clear interface based on the 3D model of the area. The following sections present the details of the methodology and discuss preliminary lessons learned from the implementation of the survey in Baqa'a. Some of them might be useful to planners and policy makers working in any other international urban context showing similar issues.

28.2 Applying CIM in Challenging Urban Contexts: An Overview

The rapid evolution of ICTs puts pressure on the progress of Smart Cities (Chui et al. 2018), as residents, public decision makers, planners, and developers have to constantly adjust to global trends, and sometime innovations are parachuted on the ground without adequate awareness and promotion policies provided by local government. In an overall perspective, examples of IT tools applied in the field of Smart City research include interoperability with GIS and CityGML (Bruno et al. 2020; Jawaluddeen et al. 2021), digital survey techniques as aerial photogrammetry (Remondino et al. 2011) and LiDAR systems (Barba et al. 2021), Virtual and Augmented Reality (VR and AR) (Chui et al. 2018; Banfi and Previtali 2021), Building Information Modelling (BIM), and Artificial Intelligence (AI) (Murphy et al. 2011).

Despite of such a wealth of technologies available, a recent systematic literature review of 80 papers on CIM skimmed from an initial sample of 1.089, showed how CIM is far from being fully established in the practise and still a gap persists between the wealth of available technologies and their deployment in support of better planning and decision making (Souza and Bueno 2022). Narrowing down the CIM application to challenging contexts, e.g. informal settlements, non-traditional urban areas such as refugees' camps, and context where scarcity or inconsistency of data hinder the implementation of CIM, examples are even scarcer, although promising.

Examples show how gamification can be a suitable solution to engage with citizens and enable community participation, as in a project developed in Maputo, Mozambique (Ghorbanbakhsh and Paio 2021), which examines the critical issues in sub-Saharan Africa such as weak economic and social infrastructure and high poverty level (about 70% of people lives in informal settlements in the Mafalala area). Virtual Reality and Augmented Reality technologies allowed to work with locals in an interactive and iterative fashion, rehearsing various strategies of action, and collaboratively evaluating the quality of public spaces.

An example of how to manage the sewage network by focusing on preventive actions and allowing a decision-making process based on accurate information is developed in the city of Piumhi, Brazil (Melo et al. 2019). A study carried out by the Treats Brazil Institute in 2014 flagged up severe delays in the delivery of sanitation infrastructure against international standards. Universal access to basic sanitation services is still far to be achieved and this, affects not only people's health by causing pathologies, but also the economy by negatively impacting the environment. The development of a reliable database will allow the identification of problems and the comparison of the conditions and characteristics of the existing networks, allowing the SAAE (local Water and Sewage Public Provider) to define assertive actions to improve infrastructure performance and generate savings in financial resources, equipment, and manpower.

Computational Design can be used to test different scenarios, such as in the case of the optimization of the spatial design of refugee camps in Diekirch in north-eastern Luxembourg (Daher et al. 2017). Through Computational Design, it has been possible to rapidly test scenarios of camp development on several locations, linking usage requirements (mostly quantitative data) to alternative design solutions automatically generated based on constraints and limits identified by the users.

Finally, Geographic Information Systems proved to be a valuable instrument to support better planning in informal settlements, as it has been tested in the city of Windhoek (Namibia), which is facing major challenges with respect to future water supply (Mosbach et al. 2022). In this case, an approach for the sustainable and practical planning of a piped Water Distribution System (WDS) in unplanned or unstructured areas. The methodology is linked to a geographic information system (GIS) to directly visualise the impacts and effects of the planning and decision-making process.

28.3 Methodology: Al Baqa'a Camp as Case Study

As previously mentioned, this study focuses on a single case study, the Al Baqa'a refugees camp in Jordan and it has been investigated through a mixed methodology, to incorporate both data on the materiality of the place, and on habits and difficulties experienced by locals.

The Al Baqa'a camp is established since 1969 due to the conflict between Palestine and Israel, many challenges are arising front of refugees in terms of fleeing from war and find a place that might be as space for a while however the situation was not easy and the case between Palestine and Israel is complicated. The camp is changed from 1969 until today, between tents, caravans, and actual houses were made by cement. In fact that the refugees are increased by time which effects on infrastructure and water sources. So based on history of the camp development, the refugees were dreaming to back to their home town (Palestine) which is impact and play a role in shaping the camp as it is today. Thus, refugees are affected on shaping urban spaces inside the camp. In this regard, refugees were trying to increasing their population inside the camp to have a good chance of their back to Palestine as demographical point of view. Aburamadan (2017) mentioned that the social consideration is the way of figuring out and articulating a solution of inadequate urban spaces and poor infrastructure, while refugees are shaping their spaces on behave of social aspect for back to home town then the only way for reorganising urban spaces inside the camp must be under social aspects (Aburamadan 2017). The area has been chosen as due to inconsistency of data available and to the complex political and socio-economic situation, which from the one hand, challenge the implementation of a CIM platform, from the other hand, would make the implementation of a CIM platform particularly beneficial both to support better institutional collaboration and community engagement.

Al Baqa' (Figs. 28.1, 28.2 and 28.3) is officially the largest Palestinian refugee's camp since 1967 in Jordan and one of the United Nations Relief and Works Agency's 10 officially registered refugee camps in the country. The camp lies 20 km north of Amman, the Jordanian capital, being consolidated into an informal city and challenged by rapid population increase. This means that the existing infrastructural capacity in the camp, which is limited and in urgent need of repair and often replacement, is being shared and further eroded, which in turn leads to socio-economic tensions within the camp and its community (Anon 2016). The Al Baqa' camp which became as informal city due to three generations are establishing in the camp due to the political situation of Palestinian conflict with Israel, so the population is increasing quickly, and infrastructure was not built to accommodate more than 120,000 refugees.

In terms of numbers, the camp is densely populated. While in Jordan the density of population is 64 persons in one kilometre square, the density of Al Baqa' area is around 200,000 persons in one and half kilometre square, thus exacerbating impact on environment and leading to increased pollution, shortage of services, flaws on sewage efficiency, and waste management.

28.3.1 Aim of the Proposal and Research Direction

Al Baqa' is suffering from shortage of resources, services, and demanding on socio-economic impact on the area. The proposed City Information Modelling (CIM) system documents water management and water sewage system and produces a prototype demonstrating the potential of CIM to develop and implement more sustainable urban management and strategies in accordance with the Official Development Assistance (ODA) programme for Jordan.

The research is focusing on using technology in finding the solutions of urban development in areas are overcrowded or density spots. While the Al Baqa' camp is an example or a pilot of presenting the possibility of using technology (CIM) in general in detecting the challenges and finding opportunities by using technology. In addition, using technology does not mean of ignoring social and cultural aspects which is basically CIM approach combines social and cultural aspects to technology.

Project team are applying digital technologies of data acquisition including Ground Penetrating Radar (GPR) and Terrestrial Laser Scanning (TLS) to develop an accurate 3D network of pipes for the sewage system and water system at the Al Baqa'a camp. It will build on the data collected through scanning digital technologies which have captured water usage data by Al Baqa'a wider residents across the camp. This will be made by creating an open web data platform, thus allowing gathering data simultaneously on multiple variables and from end-users through active community engagement.

The present paper focuses on the first phase of data acquisition by using digital surveying techniques and presents the initial findings from the fieldwork conducted in Al Baqa'a in 2022 (Fig. 28.4).

Architectural surveying is an evolving field that has changed significantly during the last decades due to technological advances in the field of 3D data acquisition (Balletti 2021). Currently, the use of digital technologies such as

Fig. 28.1 General overview of the refugee's camp. *Source* Muslim village

Fig. 28.2 A mural painted by residents narrates the evolution of Baqa'a. *Source* Authors' photo

Light Detection and Ranging (LiDAR), Aerial Photogrammetry, and Wearable Mobile Laser System (WMLS) are leading in the field of surveying (Barba et al. 2021). The final output, after careful data processing and elaboration phase, is a 3D point cloud: a three-dimensional, navigable, and interrogable model faithful to the reality.

Fig. 28.3 A dense urban fabric has replaced the original tented camp. *Source* Authors' photo

Fig. 28.4 Qualitative data on water usage and health issues related to water pollution were collected through unstructured interviews with residents. *Source* Authors' photo

On the other hand, the range of Ground Penetrating Radar GPR applications is growing quickly, as this technique is now capable of producing high-resolution 3D volumetric images of the shallow underground providing information on both the subsurface stratigraphy and the characteristics of the encountered material. Most GPR developments in civil engineering focus on the detection of rebar and other linear metallic targets, as well as hidden utilities, both metallic and non-metallic, such as pipes and cables. The main findings of GPR within this application field are piping distribution and dimensioning, identification of utility material type, fluid/void ratio in case of non-metal pipes, leakage detection, rebar configuration and dimensioning, and corrosion (Ayala-Cabrera et al. 2011; Lombardi and Solla 2022).

Finally, the project includes direct observation of the site and interviews with residents of the pilot area, aimed at incorporating the tacit knowledge of locals into the CIM dataset and supporting the creation of an interactive app allowing data collection from residents. This latter is under development and this paper expands on the lessons learned from the GPR and 3D laser scanning data gathering and elaboration phase. However, it is essential to mention that the ultimate goal of the proposed CIM is not only to test an integrated database incorporating a GPR-based dataset and the pilot area 3D model, but also to make this CIM platform accessible to non-technical users such as locals, and to create an interactive website showcasing the 3D model of the pilot area to encourage data collection from the ground.

28.3.2 Data Presentation

Data acquisition has been developed though four steps: project scoping; underground scanning based on Ground Penetrating Radar GPR; 3D survey and restitution of the pilot area based on

Terrestrial Laser Scanning; questionnaires and interviews with residents in the pilot area.

The target area and topic were decided through a focus group, delivered virtually due to the Covid enforced isolation in place in Jordan at the time and impossibility to travel, complemented with further non-structured interviews with local experts, conducted initially via web and once the pandemic related restrictions were uplifted, in person and finally preliminary fieldwork in Al Baqa'a. This stage allowed identifying the core environmental issue for Baqa'a (i.e. water management) and subsequently, the most suitable area for testing the prototype (the pilot area in Fig. 28.6).

A first visual inspection of the site confirmed issues raised by experts in the scoping phase. In addition to the above-mentioned overpopulation and the consequent insufficient sewage system, various factors that have a significant influence on environmental pollution. When heavy rainfall occurs, overflow contaminates potable water with serious consequences on health. Poor waste management adds further pressure on the environment. Large containers are placed between the houses, becoming the main source of environmental pollution. Lack of suitable space for commercial activities adds more pressure on open spaces, increasing the level of waste.

Following this initial phase, the survey started, based on the identification of a range of suitable areas conducted in collaboration with local experts and the City of Baqa'a office, on preparation of the data gathering phase through digital survey technologies, such as Ground Penetrating Radar (GPR) and Terrestrial Laser Scanning (TLS) (Fig. 28.5).

The first hypothesis was to focus on the main street of the camp but being a mostly commercial area and plagued by heavy traffic, the initial trial survey was challenged by issues such as threats to the costly and fragile Laser Scanning equipment. Then, it was decided to opt for a quieter pilot area, with limited traffic. Still in collaboration with local experts, the second and final choice was an area not on the main street, but rich in different land uses. The identified pilot area hosts a combination of activities, including public infrastructures, mosque, health centre, schools, residences, and a cemetery.

Due to the type of activities in the area, the team had to rearrange the fieldwork schedule in order to avoid peak hours for schools and other main activities, when a large number of people in the street and particularly many children out of school, lowered the quality of the results in terms of the level of rumour in the point cloud obtained. Therefore, the team decided to reschedule the work early morning only.

For what concerns the 3D model of the pilot area, an initial hypothesis of using drones was made. However, because of both legal constraints in the use of drones, and of the urban fabric of Baqa'a, which is too dense to allow using aerial scanning technologies for surveying, this was not possible. It was therefore decided to shift towards Terrestrial Laser among the LiDAR technologies, Terrestrial Laser Scanners (TLS) can have a wide range of applications in the documentation of Cultural Heritage, from small objects to large complex buildings, due to real-time data acquisition on a real scale, high accuracy and high speed and the production of a large number of points (Hassani 2015). In the present case study, the fieldwork was carried out by SurveyTEQ, industrial partner in this research project and expert on data acquisition in Jordan using as instrumentation a Leica BLK360, a TLS by Leica GeoSystems. This instrument is the smallest and lightest imaging laser scanner available on the market and it is composed of a spherical 3-camera system of 15 M pixel and a thermography panorama sensor system with a range of action respectively of $360° \times 300°$ and $360° \times 70°$.

The first step of survey design should first define TLS station locations to ensure the complete coverage of the area at the required spatial resolution. Being an external area with a main street of approximately 650 m in length, the resolution of the instrument was set to 6 mm in 10 m and a total of 82 scans were collected ensuring overlap between the individual scans of a minimum of 60%.

On the other hand, when starting GPR data acquisition there were some issues to be addressed: on streets made of concrete, where the

Fig. 28.5 SurveyTEQ performing digital survey with BLK360 laser scanner on the school street

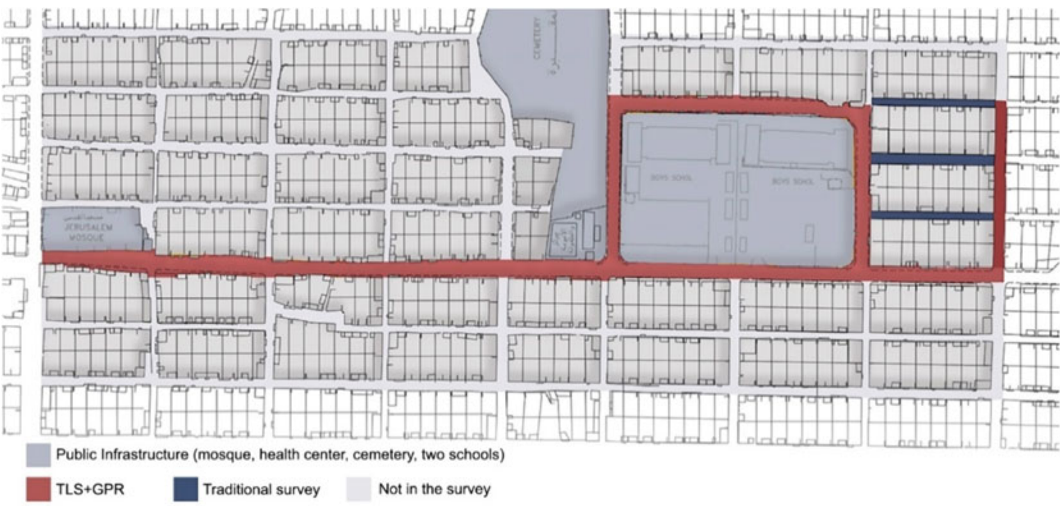

Fig. 28.6 Floor plan of the working area, indicating with colours the different survey techniques to be developed

presence of moisture and steel mesh tends to attenuate the radar signal, or where the contrast between layers is minimal (such as between concrete and granular base materials), the data acquisition did not perform successfully. Another influential factor may have been surface roughness, which disperses the incident GPR wave, making it difficult to analyse the received data and difficult to predict the effective propagation waveform.

Therefore, Fig. 28.6 represents the different survey types according to the street material: the main street, shown in red, is built in asphalt and is suitable for GPR surveys and TLS. In blue, are highlighted the concrete streets where a manual survey was carried out with traditional techniques taking as a reference the average of the measurements for the rest of the concrete streets. On the other hand, the rest of the streets are built in concrete and the instrumentation is not suitable for the GPR survey.

Finally, the fourth and last stage of data acquisition included interviews with residents and questionnaires, which is still ongoing at the time this paper has been written. The purpose of this fourth stage was twofold. The team gathered in-depth data from residents on data usage habits and on issues related to poor water management. Interviews were administered in Arabic by female researchers, as the perspective of women on this issue was considered essential. It has to be highlighted that the team was warmly welcome by locals, demonstrating how the social fabric in Baqa'a holds very positive values and is committed to improve. Questionnaires were distributed to a sample of 100 residents, to acquire more widespread data on issues similar to those investigated more in-depth through the interviews. The second goal the team wanted to achieve through the interaction with residents was to pave the way for the delivery of an app, which is under preparation at the time this paper was written. The app will be based on the 3D model as per the previous phase and will allow residents to upload data on an interactive webpage, thus ensuring sustainability to this project over time.

28.3.3 Data Analysis

This section of the paper focuses on the analysis of the data, whose acquisition has been completed at the time the paper was written. Future publications will present and discuss the outcomes from the fourth stage of this research, including outcomes from the delivery of the app and related lessons learned. In the data processing phase, the Leica Cyclone REGISTER 360, and Cyclone 3DR as an extension, software was used, which is directly linked to the laser scanner via an app on the mobile device. Through this app, the laser scanner transmits both the acquired images and the point cloud data of single scans to the mobile device via Wi-Fi. The advantage of this device is that it enables automatic data transfer (Fig. 28.7).

As mentioned above, in the registration phase of the TLS scanner, the clouds are characterised by a high degree of overlapping. Due to this, the first step was to perform a visual registration for each pair of scans by applying a Global Bundle Adjustment (GBA) (El Hazzat et al. 2015) procedure in order to optimise the 3D structure and visualisation parameters. Given the set of scans, the algorithm searches for all possible connections between pairs of overlapping point clouds. For each connection, a pairwise iterative closest point (ICP) algorithm is performed and the best matching point pairs between the two scans are saved. A final non-linear minimisation is run only between these matching point pairs of all point pairs of all connections.

Following the registration phase, the next step was to clean the data (unwanted features) by applying filters for noise, cars, and people in order to obtain a clearer geometry of the original urban configuration (Fig. 28.8). The final step, before proceeding to data verification and export, is to assign the acquired coordinate system: in this case study, the particularity was that it worked with a Cassini coordinate system used in Middle Eastern countries.

Figure 28.5 clearly expresses at the level of data restitution (3D point cloud), the informality found in the constructions: irregular settlements that were built in different periods without respecting regulations and above all compromising the structural function and the existing sanitary system. Only one repetitive logic can be observed: the ground floor of each unit presents a commercial activity, while the upper levels are composed of the houses of the local residents.

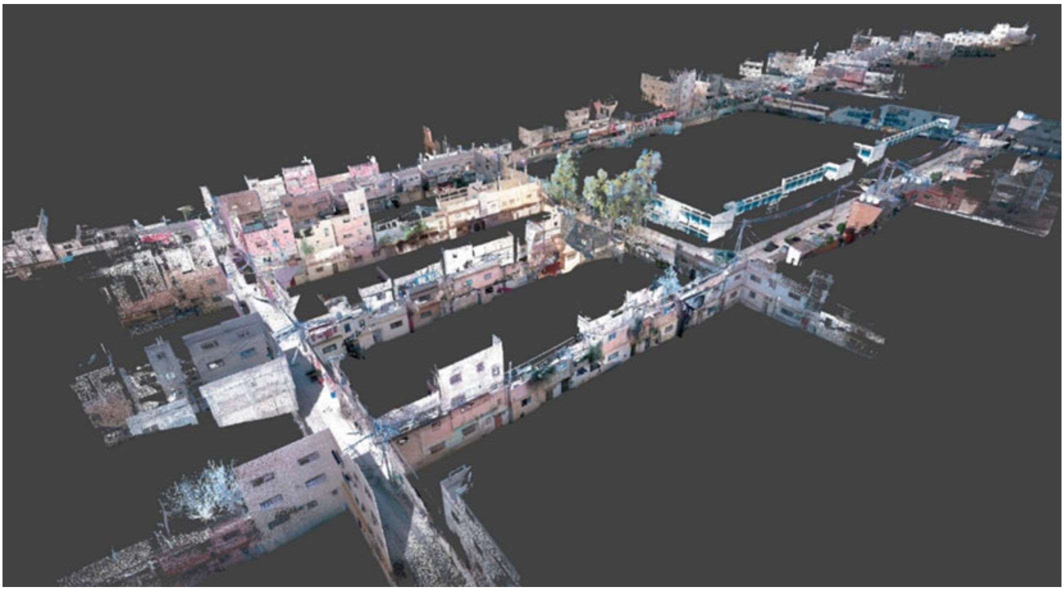

Fig. 28.7 General overview of the whole point cloud in Autodesk Recap Software

Fig. 28.8 Screenshot of the point cloud showing an urban front after applying the noise reduction filter

28.4 Findings and Preliminary Conclusions

The methodological approach in Al Baqa' camp is based on two multidimensional collecting data by in-depth interviews and focused group discussion. The most topic refugees are focusing on how much they are satisfied to the Al Baqa' or via versa in terms of several criteria of being safety and secure economically and socially. In this regard, the team work is conducted eight interviews which is includes on the following codes of positivity of Al Baqa' as place to live or negatively of the Al Baqa' place to live as the following table:

Codes	Responses by refugees
Positives about Al Baqa'a	Of course, it can improve, there is a future for it, and it has produced many accomplished people. Many young men and women have been able to find success here. And as far as improvement, it improves over time, every once in a while, they do things to upgrade it

(continued)

Codes	Responses by refugees
	As far as the changes, there have been changes over time for sure. The camp used to be made up of tin houses and now it is stone and concrete building. The houses on the inside are nice, people have nice furniture and drive modern cars
	If you have good neighbours then it is a comfortable situation
Negatives about Al Baqa'a	It is not the safest place to live, there are all kinds of trouble makers here, especially in this neighbourhood, and it is very bad sometimes I can hear them outside our window selling drugs, they come in groups and do drugs here which causes troubles and then the authorities come. All of this affects us. Everything here has issues, as far as health, our houses always have humidity issues, and it is surrounded by buildings the sunlight does not come through. There is no ventilation, you have to keep the electricity on, or you can't see I have only one room in the house with sunlight
	The living conditions are tough. The financial situation makes it difficult to live here. The sewage system here is very bad
	The overcrowding. It is a camp still, we are proud of being of the camp, it has produced world-class doctors and scientists and so on but the situation there is not the most sanitary or healthy. The population density, the environment, the cleanliness, amongst other issues (make the camp a bad pace to live). The level of sanitation is really bad and the health services are bad, the agency doesn't provide proper medication, the environmental factors are not great either

As the table is shown if refugees are satisfying of living condition in Al Baqa' in terms of service provision and adequacy of services, this paper discusses preliminary findings and conclusion from the implementation of CIM to a challenging urban settlement, Al Baqa'a. Already at this preliminary stage, a few lessons can be shared:

1. Settlements similar to the Al Baqa'a have a high degree of complexity due to the extremely dense urban fabric. Using aerial scanning technologies may be not possible, unlike many other urban environments for which 3D models are available. This has an impact on the costs of surveying and has to be considered in planning and budgeting.
2. Challenging urban settings add a layer of complexity in terms of safety and security of costly equipment. This has to be factored in whilst both scheduling fieldwork and arranging the team allocation on site.
3. Surveying dense urban environment with TLS technologies has to be planned carefully, by taking in account peak hours of the main activities run in the area, this is particularly relevant in combination with point 2.

For what concerns the follow up and expected results from the integration of data from the surveys and primary data derived from interviews and questionnaires, complemented with direct observation of the site, the following table condenses the conceptual framework that the team is using to assess the outcomes of the application of this novel CIM approach. This will be done by integrating qualitative data and knowledge derived from interviews and questionnaires on the same CIM dataset where data from stages 2 and 3 are collated. Such an integrated approach is expected to produce results according to the three pillars of sustainability (environmental, social, and economic) as per the Table 28.1.

In conclusion, applying CIM technologies to improve planning and decision making in an area such as Baqa'a and engaging with residents through digital technologies can help pursuing the New Urban Agenda 2030 and associated Sustainable Development Goals. Lessons learned in Al Baqa' can help succeeding in applying CIM to similarly complex context as Al Baqa' is a very comprehensive example in terms of the interrelationship between agencies: governmental

Table 28.1 Presentation of the results on the basis of the three main pillars of the research

	Integrated CIM
Environment	CIM enables the collection of data on water use by Al Baqa'a residents across the camp through an open web-based data platform. This demonstrator allows for cross-analysis of interrelated data from different sources
Society	CIM will ultimately produce an open access platform, allowing residents to interact with city planners and feedback on water usage and water related issues. This will allow creating a real and proper Al Baqa'a model, removing the stigma that still persists on living in this area. Moreover, the CIM platform will act as catalyst for social participation and therefore community resilience
Economy	By uplifting the socio-environmental context and helping to overcome the socio-economic stigma still existing on the Al Baqa'a, the CIM project will help economic activities and retail in particular to thrive

bodies, local NGOs, the Palestinian Refugee Office, and the United Nations Relief and Works Agency (UNRWA).

The responsibility for improving and preserving services in the camp is therefore a complicated one. From this point of view, the use of digital technologies to improve the existing situation is crucial. The use of TLS and GPR to obtain a 3D restitution and its application in a pilot project (Al Quds Street) within the camp is a first step to prepare a more widespread intervention, based on the lessons learned from the pilot area.

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