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LONG-TERM EVALUATION OF POST-DISASTER RECONSTRUCTION AND URBAN TRANSFORMATION - THE CASE STUDY OF AIGIO, GREECE

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Abstract

This paper focuses on long-term evaluation of post-disaster reconstruction and impacts of natural hazards on urban transformation.

After a destructive event reconstruction presents an inevitable necessity which pursues to designing a process that readjusts the system while improving its capacities to sustain against predictable risks. The emerging situation is often perceived as an opportunity, because the approach towards post-disaster reconstruction predestines whether catastrophes can act as a catalyst for modernization or as a constraint for further development. Experiences from historical and recent reconstruction processes reveal the crucial problem: transformative change is caused by disasters, not by design. There is a lack of interdisciplinary cooperation and integrated approaches that consider the socio-spatial interrelations while accounting for long-term strategic development and the evaluation of the post-disaster reconstruction in order to adjust the system against newly arising risks.

Based on a systematic building stock elaboration this study analyses the effects of the destructive 1995 earthquake on the urban development of Aigio, Greece. Three building surveys were operated at various times and with sufficiently large distance. Starting after the earthquake (1995), including results of detailed damage surveys, continued into 2005 (ten years after the earthquake to consider the reconstruction process) and a recent evaluation in 2013. This long-term evaluation allows comparing foreseen reconstruction measures and actual occurring urban transformation by considering the changes of pre vs. post-event vulnerability and resilience capacities of the built environment within a 20 years covering time frame (Delta 'Δ'-Consideration). For each survey the analysis applies the Vulnerability Classes according to the Construction Types defined by the European Macroseismic Scale 1998 (EMS-98). The EMS-98 can thus be transferred as a tool for disaster risk reduction on the scale of integrated urban development concepts. This appears reasonable as the insights of the study let to the conclusion that the single building, but also the large scale engineering approach, is not sufficient to reduce disaster risks; especially when taking into account the incorporated multi-hazard assessment and the lack of an integrated approach that combines engineering and urban planning considerations during post-disaster reconstruction. Therefore a complementary Urban Resilience perspective is presented which integrates the interrelation of social processes and built environment into the engineering approach. Interdisciplinary cooperation generates the synergies needed to integrate disaster risks reduction within an urban development process that creates change by design, not by disaster.

Keywords: Post-disaster Reconstruction, Urban Planning, Urban Resilience, Building Typologies, EMS-98

1. Introduction

According to the UNISDR 2015 Global Assessment Report on Disaster Risk Reduction, within the last 20 years disasters affected 4.5 Billion people, causing the death of 1.3 Million. Damage costs are estimated to USD 2 Trillion, which equals 25 years of development assistance; by now average annual costs reached USD 300 Billion [1]. Throughout human history earthquakes are by far the most deadly natural hazards, most devastating if amplified as multi-hazard event. Also within the last 20 years about half of the people affected by extreme events lost their life due to the impacts of earthquakes.

As a consequence of these existential threat to sustainable development, a far-reaching re-conceptualization of the analytical and strategic approaches occurred during these last decades. Asserting to reside in and design the 'Anthropocene', gave an emerging understanding of disasters as social constructs. Natural hazards are natural phenomena, while disasters are the socially determined and constructed impacts (see e.g. the rejection of the term 'natural disaster' since the end of the International Decade for Natural Disaster Reduction) [2], whose severity is mediated between the interaction of hazards, vulnerabilities and resilience capacities. This paradigm expedited the subsequent shift from a hazard-oriented approach towards the still rather reactive-analytical concept of vulnerability and the current rise of proactive resilience strategies.

Today the majority of human beings live in urban areas, the implications of these 'Planetary Urbanization' [3] as well as the predictions and impacts of climate change define the current debate on 'Urban Resilience', a concept that still lacks coherent theoretical basis and practical application. The paper intends to tackle these topics by briefly resuming the gaps and problems as well as presenting methodology and tools for a long-term evaluation of post-disaster reconstruction. For the model study of Aigio (Greece) an integrated approach has been proposed that can help improving urban resilience and generate sustainable urban development.

2. Types of Reconstruction

Cities are agglomerations of humans, their assets and values. They are the driving force of economic growth, most vulnerable and simultaneously the incubator of innovations. Their extensive, often unplanned urban development and excessive consumption is concurrently causative for the occurrence of the most severe disasters. As ensuing reconstruction efforts were all too often guided by one-sided short-term relief through structural measures, insufficiently coordinated and rarely monitored, disasters tend to reoccur, eventually not initiated by the same agent, but yet due to the interference of multi-hazard events. Therefore, vulnerability analysis as well as resilience strategies necessitate relating to an elaborated evaluation of the reconstruction process that incorporates a multi-hazard assessment in order to accord for effective disaster risk reduction. This includes interdisciplinary cooperation to develop complementary perspectives that follow an integrated approach to decrease the uncertainties that arise from the multitude of existing risk factors.

The impact of natural hazards on urban settlements was studies by Schwarz (2015) [4] combining earthquake engineering and urban planning within a complementary perspective in order to address multi-risk factors more effectively.

Even though there is neither a comprehensive database nor consistent terminology, Reconstruction Types can be defined based on analysed historic cases and categorized by using the scale of occurred intervention. Five basic types of reconstruction could be distinguished (see Fig.1).

Reconstruction types are reaching from the absence of reconstruction (Extinction) to individual rebuilding within the settings of the current regulatory frameworks (Rebuilding) and the Retrofitting or renewal based on technical innovations (Restoration) up to an urban scale, including the redesign of the urban fabric with the introduction of new building types (Redevelopment) and the total relocation of towns (Resettlement). However, the types described tend to blend as reconstruction measures vary, displaying the need for further refinement on different levels (urban scale interventions, building typologies, reconstruction measures).Throughout history reconstruction approaches varied; defined and exemplified based on historical and recent events five development phases (I to V) can be categorized.

I. Pre-modern interpretation and response: Examples like the extinction of Helike (near Aigio) or Pompeii reveal the severity of single hazard risks. While the case of Villach (Austria, 1348) Earthquake displays a pre-modern approach with religious interpretation that restrain improvements and planning interventions.

II. Rise of rationality in risk reduction and planning: The Lisbon 1755 earthquake and tsunami marked a major change in the approaches to post-disaster reconstruction. Embedded in the discourse of the Enlightenment, rational approaches to analyse the causes and measures to improve the built environment were introduced (rationally urban redesigned, aseismic building designs).

III. Transiting into rational-comprehensive Planning: Paradigm shift towards modernity appeared as displayed in the cases of Zagreb 1880, Ljubljana 1895 or San Francisco 1906 where damage surveys scientifically researched the effects of the earthquake and defined measures for repair. Protection and technical feasibility gained importance, while the earthquake was used to introduce interventions in the urban layout.

IV. Responding to natural hazard in times of planning euphoria: Along with the rise of rational-comprehensive planning and the affirmation of technical progress also the reconstruction process changed. The Alaska Earthquake and Tsunami in 1964 revealed the variety of reconstruction types (Valdez: resettled, Seward: redesigned, Anchorage: small scale redevelopment projects) mixing market-driven and state-subsidies approaches. In contrast, the Tashkent 1966 earthquake displayed how planning euphoria for post-disaster reconstruction resulted in a tabula rasa style destruction of the existing urban structure, implementing a new, seismic resistant, soviet city. Skopje 1963 is another important example for comprehensive redevelopment.

V. Contemporary approaches and tendencies of recent events: Contemporary approaches to reconstruction display the variety of types and the gap between elaborated theoretical concepts and the idea of integrated approach for disaster risk reduction and actual reconstruction: Aceh 2004 (emergence of build back better approach), Christchurch 2010 (urban design concept, master plan), L'Aquila 2009 (long-term approach, but unclear future perspective for reanimation of inner city), Port-au-Prince 2010 (lack of strategy and coordination, reoccurrence of disasters), Fukushima 2011 (nuclear contamination), Nepal 2015, Ecuador 2016.

Only few long-term evaluations of post-disaster reconstruction processes and no comprehensive study concerning the impact of natural hazards on urban development on a single-building scale within a 20-years time frame are available. In addition, the examples of implemented integrated approaches that follow urban resilience strategies are rather limited, not at least the theoretical basis falls short. Recent events (e.g. Haiti 2010, Japan 2011) display that single dominant, but especially the cascades of multiple hazards events overstrain the rational predictions and technical protections, resulting in disasters, in both, developing as well as highly developed countries. Reconstruction remains an inevitable necessity that inhere the chance to cope with the initiated change by decreasing vulnerability and enhancing resilience capacities.

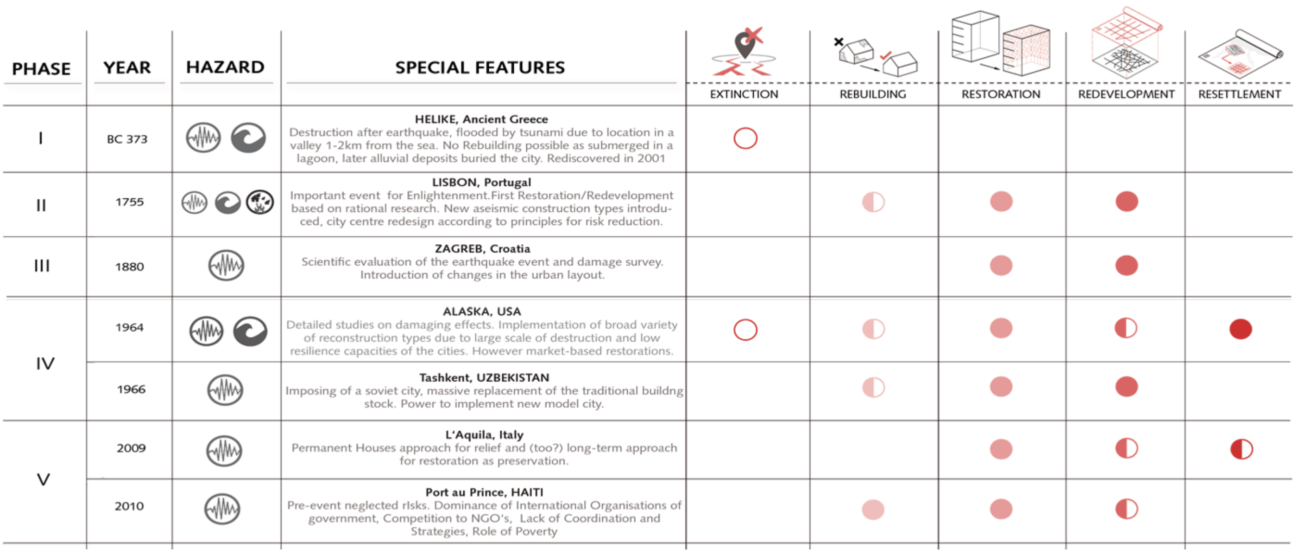

Fig. 1 – Historical examples and applied types of reconstruction [4]

Experiences from historic and recent events reveal the crucial problem why this 'window of opportunity' often ends as a 'lost opportunity': transformative change is caused by disasters, not by design. Analysing past and recent disastrous events, the ensuing reconstruction process, its conception and implementation, enables to derive the underlying reasons for this shortfall. The reconstruction of Aigio exemplifies a reconstruction type of market- and state subsidies driven 'Restoration' on a single-building scale (see section 4).

3. Data and Tools for Evaluating the Post-disaster Reconstruction Process

3.1 Methodology

Including the concept of resilience is essential to design a sustainable post-disaster reconstruction process. Resilience can be defined as "capacity of a system to absorb disturbance [Authors note: Persistence] and reorganize while undergoing change [Authors note: Adaptation and Transformation] so as to still retain essentially the same function, structure, identity, and feedbacks" [5].

It is framed by three basic components: I) System's Characteristics, (II) Prevailing Paradigms and (III) Disruption and Reorganisation [5]. In other words resilience is the capacity to cope with initiated change and sustain the path from actual status (defined by the system's characteristics; requests analysis: What has changed?) towards the target status (defined by prevailing paradigms; requests strategy: What should change?) through the resilience capacities of persistence, adaptation and transformation [6]. Therefore addressing change itself appears as the linkage between analysis and strategy. Rather than describing resilience as a given characteristic of the actual status, it can be determined retrospectively by analysing the occurred change between the disruption due to the disaster impact and the reorganisation based on the implemented measures during reconstruction (before vs. after).

The tool of Δ(Delta)-Consideration was developed to evaluate the Post-disaster Reconstruction Process. It serves to systematically identify and compare the development before and after, linking disruption and reorganisation. This urban transformation analysis considers different methodological concepts to evaluate the occurred change [4]:

- Socio-Spatial Continuum (the interaction of built environment and social processes);
- Spatial levels and the multi-scale consideration recent development (Macro, Meso and Micro level), allowing to deduce general development trends, aggregate information from detailed zoom-ins, and to provide a common database for different disciplines;
- Temporal scale (based on different building survey al long-term evaluation is provided;
- Resilience Capacities; based on the different system's capacities to perform change the observable measures of urban transformation are be categorised (persistence, adaptation, transformation).
- Multi-hazard Assessment: Based on the mapping of multi-hazard exposures.

Based on these tools the Post-disaster Reconstruction Process is evaluated within a long-term observation period that considers different spatial levels and multi-hazard risks. Information is deduced from an urban scale analysis and refined by aggregated data from a comprehensive single-building survey. Urban development strategies that account for the integration of disaster risk reduction into sustainable urban development can be derived while the elaborated engineering approach is retained. Basic methodological feature is the systematic Δ-Consideration that provides data on a single buildings scale within a 20-years time frame for the case study of Aigio.

3.2 Multi-hazard Assessment

The urban development of the target city Aigio has to consider the impact of different Natural Hazards. Based on data from real events, historical observations and current research results [4], Fig. 2 provides a multi-hazard mapping for earthquake, tsunami, wildfire and flood exposure that is overlaid to define multi-risk areas that should be considered in territorial and urban planning. The exposure of urban development and critical infrastructures can thus be determined.

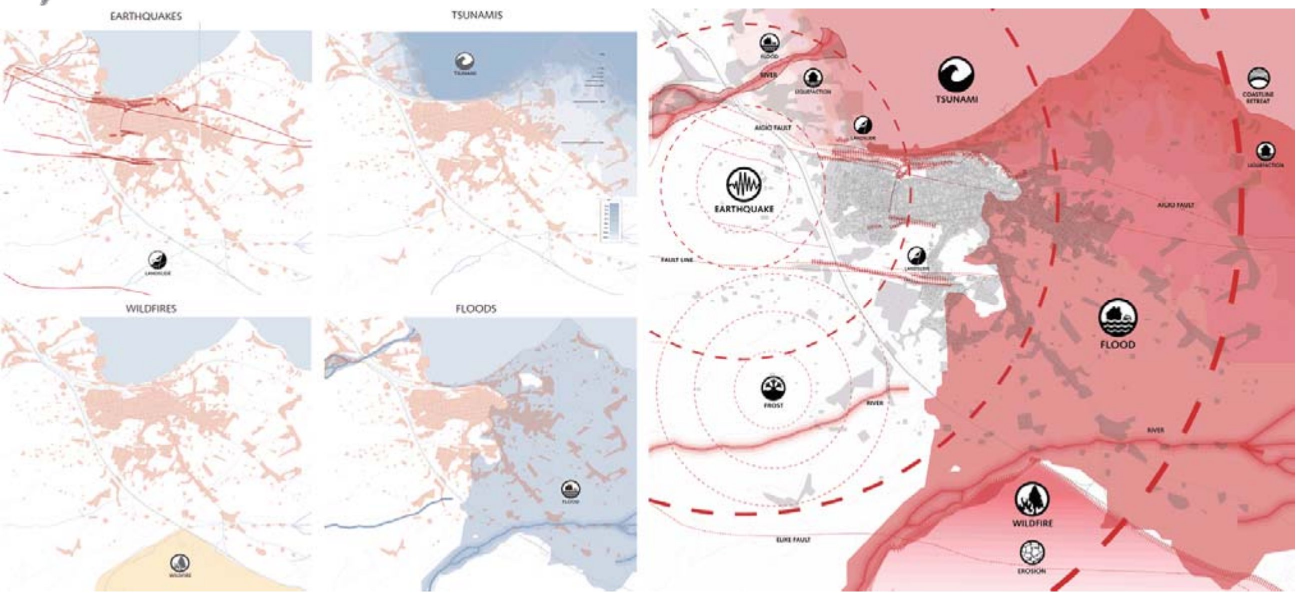

Fig. 2 – Multi-hazard mapping: Hazard exposure of Aigio (earthquake, tsunami, wildfire, floods) [4]

3.3 Macro Scale: Urban development

Aigio (also written/known as: Aegium, Vostitsa, Aeghion, Aegion, Aegio, Egio, Αίγιο) is a medium-size Greek city, located on the North Peloponnese, in the Region of Achaea, Western Greece, whose amount of approximately 26.000 inhabitants has shrunken around 10% continuously within the last 20 years.

Within its 3000 years of retraceable urban development the city passed from ancient prestige and flourishing trade, based on its harbour and demanded natural products, towards deindustrialization and stagnation in the mid 20th century. This process was portentously accompanied by the presence of multiples hazards that carved its development patterns. The cities pure persistence displays the long-term resilience, which is not at least the result of thoughtful choice of location in a multi-hazard prone area, earthquakes and tsunamis being the most impactful hazards (destructive historic events in: 23, 1748, 1817, 1861 and 1888). Besides the city shape itself, a nearby example displays the possible impact severity: the recently uncovered ruins of the ancient city Helike that was submerged by a tsunami in 373 BC - supposedly the sunken Atlantis of Plato's famous story. Even though Aigio's ancient and ottoman built heritage is nearly extinct, the period of mid 20th century stagnation preserved large parts of its 19th century neoclassical building stock that defines today's urban heritage. Aigio pure existence exhibits resilience capacity to persists, even though its built environment adapted and transformed.

Composing historic town plans, cadastral plans, satellite imagery and digital data allows reconstructing the urban morphogenesis from on a macro scale (see Fig. 3). Growing from an ancient nucleus, Aigio always had a strong relation to its hinterland. The mapping displays that this relation became increasingly overlaid by suburbanisation. Evidently rapid urban growth started with the industrialisation in 19th late century. Since the 1960s the inner city densified based on the replacement of traditional buildings by 'Polykatoikias' (the typical Greek 'multi-story building'; RC frame structures based on Le Corbusier's idea of the 'Dom-ino House').

At the same time, widely unregulated suburbanisation (peripheral urbanisation) increased. Recent expansion reveals the growth trend into multi-hazard prone areas. These tendencies (increasing density to the inner and unregulated growth at the urban fringe) form the basis of the 'Modern Greek City'. [8] Renewal to the inner city bases on the replacement of traditional building typologies and construction types (adobe, masonry) by Polykatoikias using the system of 'antiparochi' (plot-for-flat exchange between owner and contractor). At the fringe the city grows unregulated and is retroactively formalized and incrementally integrated through amendments to urban plans [9].

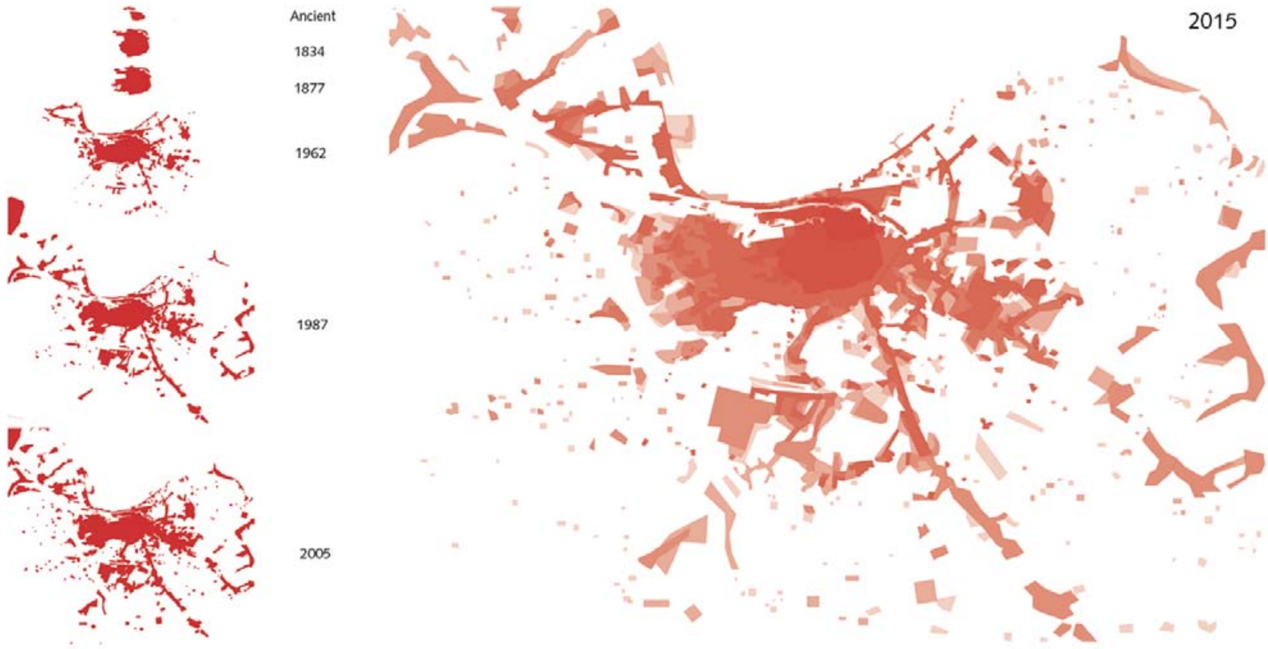

Fig. 3 – Urban development from ancient to present times (the darker the older) [4]

This complex urban development system distributes the rise of land value partially towards the owners and results in more equitable distributed and decreasing vulnerability due to the extensive renewal of the existing building stock based on a single building typology (including modern seismic codes etc.), nonetheless at the expenses of the built heritage. Furthermore, this equitable distribution of structural vulnerability is counteracted by the integration of (multi-)hazard prone areas. Rather than proactively prevent these deficiencies or mitigate them by planning interventions, urban design defects remain and transformation occurs on the basis of exceptions that result in new risks.

3.4 Meso Scale: Urban block

Shifting the focus to refine the analysis on the level of urban blocks enables the distinction of types of residential areas (A-D) as shown in Fig. 3. The underlying single-building evaluation, that includes construction types, building height and use, allows determining the range of density and use within these areas. Street sections for three intensity scales are provided. Additionally, different degrees of commercial intensity complete the basic characteristic of those area types. Furthermore actively planned districts and areas of unregulated growth can be distinguished.

Based on the photo documentation of every single building the building stock can be categorized in Building Typologies; they are assigned to the area types. Those building typologies are defined in order to complement the engineering taxonomy (including the Building Types described based on the EMS-98) and provide further insights into socio-economic properties that frame the urban resilience of the building stock.

3.5 Micro Scale: Single building

Fig. 5 describes the existing building types within the City of Aigio, based on the given classification of European Macroseismic Scale 1998 (EMS-98). The taxonomy refines the assigned vulnerability classes of the EMS-98 in order to elaborate the risk assessment. Therefore the different building types evident in the city are classified according to parameters (construction type, vulnerability classes, use, floor class, seismic codes) that were adapted for the case of Aigio, Greece. This allows combining the preliminary assessed building typologies (see Fig. 4) and the engineering perspective.

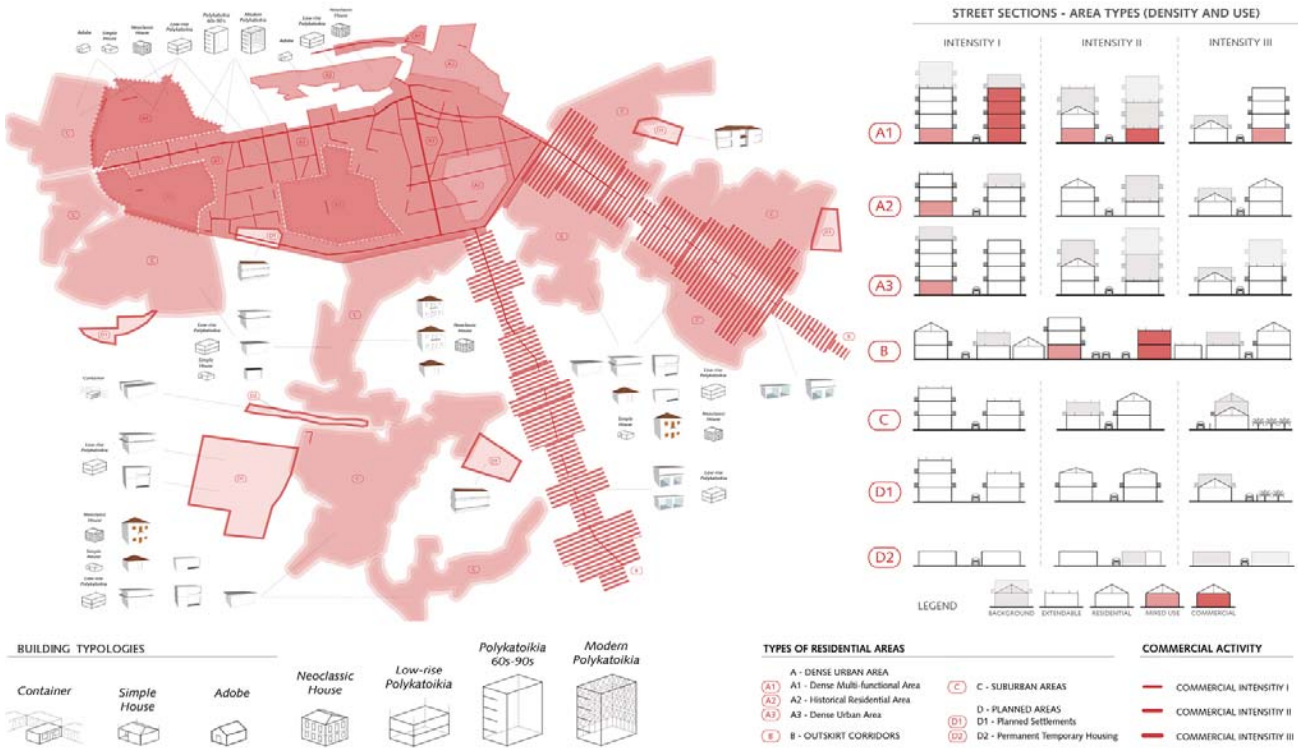

Fig. 4 – Area types, building typologies, street sections and intensity of use [4]

4. Evaluation the Post-disaster Reconstruction Process

4.1 Datasets and Delta-consideration

Basic methodological feature is the systematic Δ-Consideration that provides data on a single buildings scale within a 20-years time frame. Fig.6 displays the three underlying layers. Fardis *et al* [10] presented an elaborated damage study (2014 Buildings within the inner city, including damage grades for construction types, storeys, reconstruction measures and funding for 1995-1998) which forms the first layer used for this study. It is ensued by the detailed building survey of EDAC in 2005 that included the whole city (7590 buildings) and photo documentation for the inner city used for the application of EMS-98 to compare the building stock vulnerability within a 10-years‘ time frame[11]. This survey is the base to comparison for the third layer: the re-evaluation of the inner city building stock by the authors in 2013 (including construction type, storeys, use, conditions and vulnerability classes for 2964 buildings).

4.2 Damage caused by the 1995 and actual building conditions

In the night of June 15, 1995 an earthquake of appalling severity shook the City of Aigio (M=6.5, 26km depth, 18km northwest of the City Centre, horizontal Peak Ground Acceleration 0.54g). Within the affected region 26 People died in two collapsed high-rise RC structures, 200 were injured, only in Aigio 2.100 became homeless. Damage costs were estimated about US$ 660 Mio, while actual reconstruction funding was about 49,6 Billion Drachmas (approx. US$ 200 Mio) (Loans: 24,6 Billion Drachmas; equal amount for interest on loans provided by Greek banks; Free Public Assistance:11,7 Billion Drachmas; Restoring, including demolitions of ruins, repair of transportation network, temporary housing, operating costs, expropriation, etc.: 13,3 Billion Drachmas). Impact severity was considerably high all over the dense urban centre of Aigio, in particular around the fault line that runs through the city. 1887 buildings were destroyed or damaged beyond repair.

Special interest and intensive research about this earthquake aroused as the actual Greek seismic codes from 1984 (replacing those of 1959) undergo the first heavy reality test.

Fig. 5 – Building type taxonomy [4]

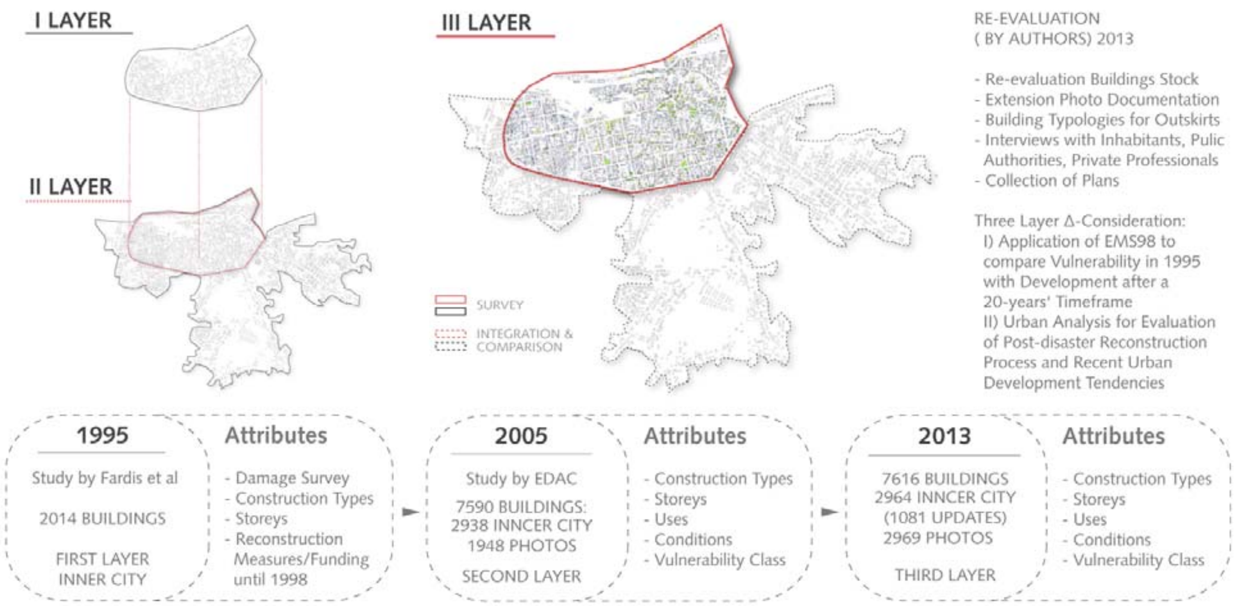

Fig. 6 – Δ-Consideration and building stock surveys 1995 | 2005 | 2013 [4]

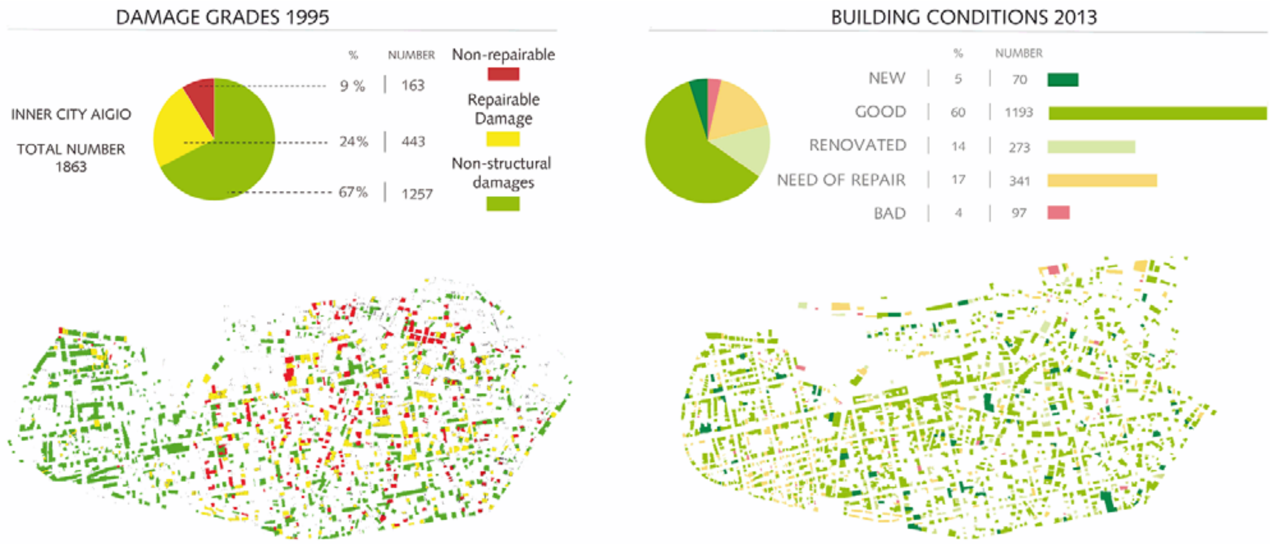

Fig. 7 – Observed damage grades 1995 [10] and building conditions 2013 [11]

Two ensuing damage surveys were conducted (1995: 3346 buildings; 24% unusable, 24% temporary unusable, 52% usable; 1996: 8155 buildings, 25% very structural damage – collapse, 28% moderate to serious structural damage, 47% undamaged or slight non-structural damage). Initiating the before-after comparison appears most logical by contrasting the occurred damage in the inner city of Aigio with the surveyed data of the actual building stock conditions in 2013 as shown in Fig. 7. During the 1995 earthquake all damage grades occurred to all building type (adobe, masonry, RC). The building stock remained in generally good conditions (1995: 67% | 2013: 79%), while the need of repair or renovation remain constant (1995: 24% | 2013: 24%) and the level of critical buildings conditions improved (1995: 9% | 2013: 4%). Understanding the relation of damage degrees and actual building conditions, however, requests for further in-depth refinement. For example, within nine years (2005-2013) nearly 10% of the building stock was renovated; however, there is evidence for an unequally spatial distribution within the city: areas slightly affected by the earthquake now suffer from maintenance backlog, thus questions arise: Which building types are renovated or replaced? What defines today's building stock vulnerability? What has changed and why? Interpreting these phenomena and their impact on earthquake resistance and urban resilience requires to quality these data by evaluating the actual reconstruction measures on a single-building scale.

Based on the available data [12] the reconstruction funding is analysed in order to determine the possible measures of reconstruction. The funding distinguishes buildings with non-repairable or repairable damage. Accordingly, the supposed types of funded reconstruction are either replacement or restoration. These 'tagging' and damage surveys predetermined the beneficiaries and excluded applicants for reconstruction funding (seismic loans). In total 5460 beneficiaries were funded: 2957 with non-repairable, 2503 with repairable damages. However, there is uncertainty about the state or repair or replacement for 2614 buildings in the region as 32% of the applicants were not approved, thus excluded from 'seismic loans'. Correspondingly, the evaluation reveals that the possible types of real action vary from this expectation and created the following paradoxes that stress the need for urban planning and long-term evaluation.

(1) Permanent Temporary Housing lasted for two decades and became permanent (no long-term commitment). Three types were supposedly provided: Emergency shelter (centralized tent camps) and Temporary housing (145 containers in locations at urban fringe) Social housing in permanent structures (delayed in the beginning due to the lack of a comprehensive cadastre, finally not constructed). After 20 years the half of the supposedly temporary houses remained in permanent use (see Fig. 8), displaying that resistance does not equal resilience and the deficiencies of the reconstruction process created new risks that determine the actual (pre-event) conditions and future impact severity. The failure in funding led to increased vulnerabilities and new inequalities displayed in the difference of post-event resilience capacities due to the malfunction of reconstruction itself.

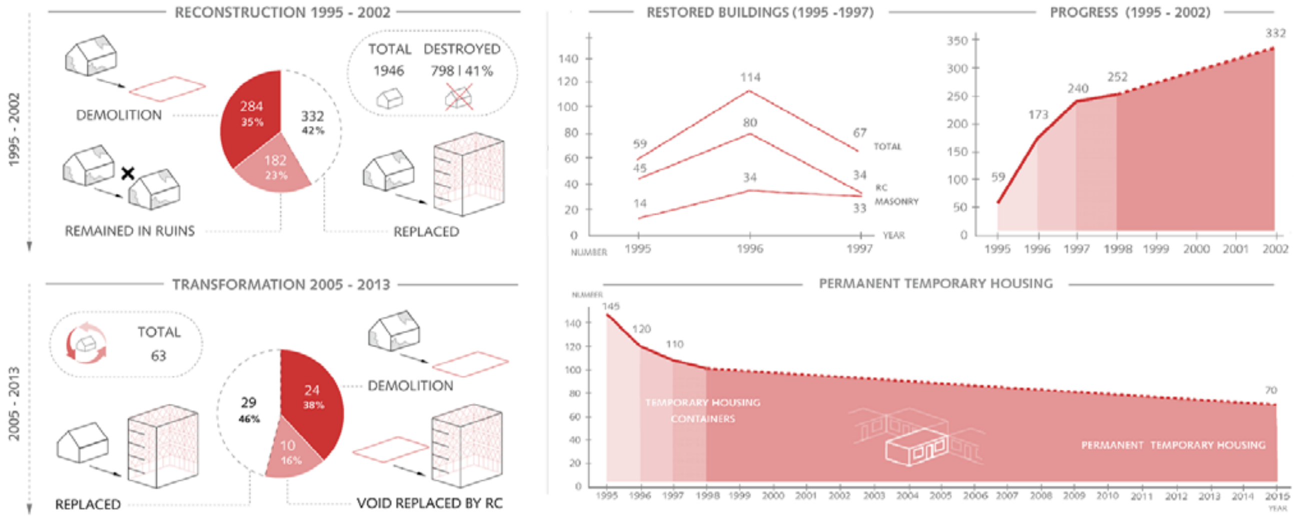

Fig. 8 – Reconstruction 1995-2002 [13] and urban transformation 2005-2013 [4]

(2) Buildings with 'repairable damage' were demolished (difference of actual damage and tagged 'damaged')
(3) Buildings funded for reconstruction were left in ruins (difference of supposed measures and real action) or were rebuilt elsewhere (promoted suburbanisation often in multi-hazard prone areas).

4.3 Types of urban change 1995-2002-2013

Available data for the first reconstruction phase (1995 until the approval of the statutory town plan in 2002) is taken from an Urban Design Study for the inner city [13]. The type of reconstruction phase can be described as a state-subsidised, but market-driven process of susceptible quality that spares proactive planning interventions. Dependencies of the centralized planning system left the local level impotent. Delays in the approval of the Town Plan (seven years) and the renewal of the General Development Plan from 1986 (still in revision) allowed individual rebuilding to determine urban transformation.

As displayed in Fig. 8 reconstruction began first hastily, using the absence of adapted building restrictions, followed by a phase of deceleration. Within this period a massive 'post-disaster destruction' occurred: while only 163 suffered non-repairable damage, 798 buildings (41% of the inner city building stock) were either replaced (42%), demolished without replacement (35%) or remained in ruins (23%). This means that nearly four-times as many buildings as tagged unusable had been destroyed within seven years. These massive changes in the building stock changed the face and identity of the city.

Two decades after the event, building activities are still related to the earthquake impacts, indicating the decelerated, but evident continuation of the Post-disaster reconstruction process. Δ-Consideration, the measures observed during the first phase can be retraced for the period 2005-2013: 46% replacement of traditional structures, 38% demolition and 16% of the voids that remained after the demolition of the first phase were now rebuilt voids remain, or were pervaded by large scale structures that changed the urban structure and influenced the previously small business retail structure (see Fig. 9). Understanding the actual significant of these observations and the transformation of urban development requires analysing the occurred changes on a single building scale.

In this second phase a continuation of the reconstruction process under circumstances defined the new urban development. New tendencies permeated the gaps left by the disaster, while general development trends proceeded to gain ground. The systematic re-evaluation of the building stock for the period 2005-2013 enables to categorise the observable measures of change in the built environment into three different types with according subcategories. Those describe the resilience capacities of the building stock to cope with change.

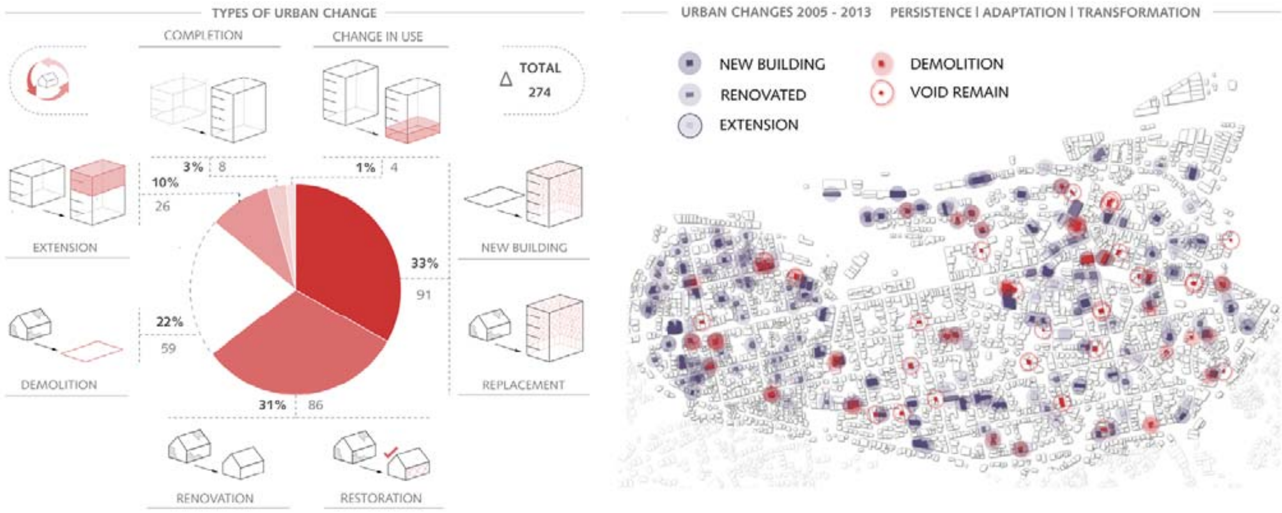

Fig. 9 – Types of change (2005-2013): Persistence | Adaptation | Transformation [4]

The following types of change have been introduced for a detailed evaluation (see Fig. 9):

Persistence (What is still there and persisted?):

- Out of the 74 classified Heritage Buildings many could have been renewed, with great efforts and very good results, however, deterioration continues, displaying the need for urban renewal program

Adaptation (What has been changed while the structure remained?):

- “Changes in Use” and “Completion” (4%): minor quantity and importance of change;
- “Extensions” (10%): expression of the incremental building process; only Polykatoikias, mostly from 2 to 3 or 3 to 4 storeys, thus partly counteracting the buildings restrictions of the town plan;
- “Renovation”/”Restoration “(31%): 3% of the building stock, mostly low-rise residential buildings of all construction types, indicating the slow rehabilitation of traditional building types, but also evidence of maintenance backlog; renewal of commerce indicates change in the small scale business structure.

Transformation (What was there before, but ceased-to be or emerged as new?):

- “Demolition” (22%): mostly traditional building types with 1-2 storeys in need of repair and bad conditions, but also speculative demolition of buildings in good conditions, including plot merging;
- “Replacement” and “New Buildings” on voids (33%): Mostly high-rise RC structures (>3 storeys) with residential use, often violating building restrictions based on exceptions and plot-merging in order to construct high-rise or large scale structures.

Expressing the impact of the earthquake damages, reconstruction and urban transformation in numbers illustrates that 31% of the building stock changed within a 20years’ time frame. Observable measures of urban change within 2005-2013 occurred to 45% as adaptations and to 55% as transformation.

5. Evaluation of urban planning approaches

The former equilibrium of building types became unbalanced as traditional masonry structures decreased by 15% (1995: 42,9% | 2013: 28,2%) being replaced by Polykatoikias (1995: 57,1% | 2013: 71,8%). The cityscape transformed, even thought the urban layout remained. New construction types were introduced (RC wall replacing RC frame with masonry infill), the amount of high-rise buildings that violate the buildings restrictions of the town plan increased, formerly unknown large scale structures permeated the voids in the urban layout, changing the urban morphology and affecting the small scale business structure. Nevertheless, there is evidence for a maintenance backlog due to lack of urban renewal projects, critical in particular as high-rise RC-structures that mostly belong to the partly failed seismic codes, the quality of reconstruction is susceptible and no evidence for renovation or restoration was found.

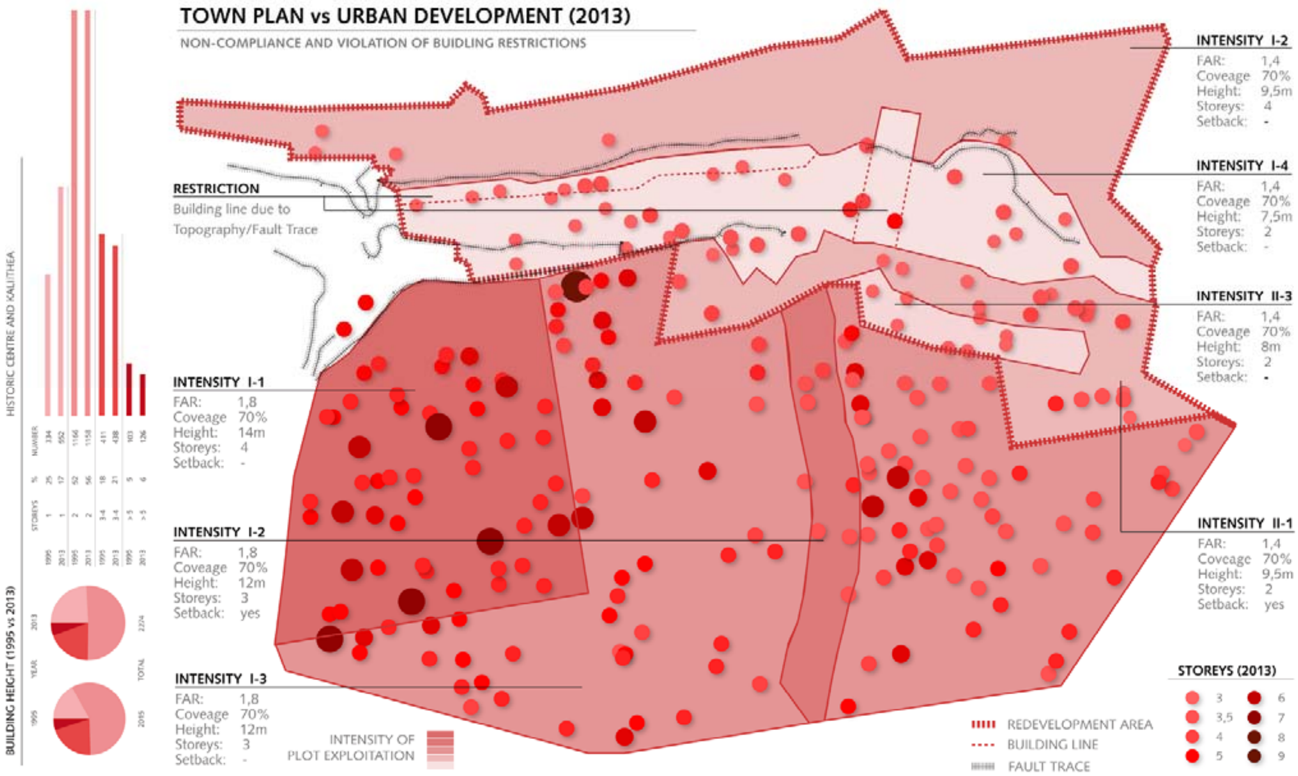

Fig. 10 – Town plan regulations and actual urban development [4]

The new pre-event conditions are framed by increased earthquake resistance on a single-building scale, while the reconstruction process proved the institutional weakness for long-term commitment or proactive planning, revealing the high conceptual vulnerability that leading to decreased urban resilience. New risks arrive from the outdated and/or ineffective statutory plans that display non-compliance on a regular basis, which is not counteracted by urban planning; restrictive engineering efforts (microseismic zoning) are counteracted due to the lack of enforcement that results from the absence of integrated approaches, long-term evaluation and proactive planning strategies.

Real transformation, as revealed by the re-evaluation, displays the actual increase of building heights (see Fig. 10). Apart from the persistence of urban design defects in the consolidated urban fabric due to the lack of intervention, the lack of multi-hazard considerations on national and local level led to a risk-intensive urban expansion. As different hazards create a variety of possible impacts, challenging different vulnerabilities, thus resilience capacities are likely to be overstrained. Earthquake resistance must be embedded into a complementary urban resilience perspective that follows an integrated approach, which mainstreams disaster risk reduction into sustainable development.

6. Conclusions and Transferability

This study presents a methodological framework for the systematic long-term evaluation of Post-disaster Reconstruction Processes. It was designed to be transferable and applicable to other contexts, using the case study of Aigio as a model area. It bases on a 20years' time frame Δ(Delta)-Consideration that generates a complementary perspectives to the elaborated engineering approaches by framing the transformation process on different spatial scales (macro: urban development) while retaining the comprehensive database for further refinement (micro: single-building scale).

The results of these Δ-Consideration act as the basis to analyse the occurred measures of actual change, wherefore urban transformation is depicted in a comprehensive and elaborated way using the resilience capacities (persistence | adaptation | transformation). It can be used to analyse the actual change that is caused by disaster, in order to design the target change in a resilient transformation process in order to sustain development and mitigate disasters. The displayed toolset intends to improve interdisciplinary cooperation to generate synergies.

Based on the results of the 20years' Δ-Consideration the impacts of natural hazard on urban transformations, it can be concluded that there is a continuation of the Post-disaster Reconstruction Process, which led to a massive modernisation of the traditional building stock including an observable acceleration of general development trends and the rise of new tendencies. Vulnerability to earthquake hazard was improved, even though the engineering approach remained party ineffective due to the inconsistent integration of urban planning. This conceptual vulnerability of the reconstruction process created new risks that redefined the resilience capacities, which frame the pre-event conditions for the next event.

A recommended approach for disaster risk reduction is, on the one hand, to the design an urban renewal project for the inner city that incorporates the EMS-98 based vulnerability classes and uses the provided insights about the recent conditions and development tendencies of the buildings stock and, on the other hand, a proactive land management for urban expansion that mitigate multi-hazard risks. Both concepts have to be integrated into a participatory process that results in a comprehensive urban development strategy.

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