MANAGEMENT OF DEMOLITION PHASES AND RELATED WASTE, IN A BUILDING RENOVATION PROJECT NEAR SALERNO, ITALY

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Highlights

In accordance with current environmental regulations, in the Italian and European context, it involves, at first analysis, an increase in costs due to the adaptation of the operations of the building process to the quality and quantity parameters imposed. These higher costs can be a painful burden for small-medium enterprises. However, for building replacement interventions, it is possible to organise the management of demolition operations according to the reuse, after recycling, of fractions of the demolished materials. This approach allows for an almost complete reduction of the initial gap, also by assessing the achievement of rewarding scores.

Abstract

Compliance with recent environmental regulations, the demolition phase, within the building replacement process, plays a decisive role, in terms of execution and management methods. The contribution addresses the problems related to the management of the site, in compliance with regulatory requirements for selective demolition and disposal of waste materials. Possible organisational and procedural solutions were investigated with particular reference to the phases of selective demolition (in compliance with Minimum Environmental Criteria), excavation, handling, treatment, recycling, and disposal of waste materials.

Keywords

Sustainability, Environmental-criteria, Demolition, Recycling, Waste-reduction, Building-site.

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1. INTRODUCTION

The problem of urban degraded area renovation is particularly complex by investing multiple impacts: social, environmental, urban, architectural. In addition to physical and functional obsolescence, over the years, there is social obsolescence, a progressive phenomenon of disownment by the community of its identity. It is mainly suffered by the suburban and intensive neighbourhoods dating back to the Second World War: "… in Italy, post-war building rubbish must be scrapped, without quality, historical interest and anti-seismic efficiency. There are about forty million rooms, built between 1945 and 1972-75, which no longer meet any of the criteria for which conservation operations are worthwhile…" [1]. According to this approach, the strategy to be pursued is to plan at 'zero volume', without consumption of new land; this is possible through environmental compensation, i.e. through demolition and reconstruction in situ [1].

Italian legislation has recently regulated the Minimum Environmental Criteria for Construction [2], for renovation and construction interventions, in accordance with the strategic objectives defined by the European Commission [3], in line with the European strategies for the construction sector and waste management, as well as with the objectives of the Waste Framework Directive 2008/98/EC, which aimed at achieving a 70% share of recycled construction and demolition waste by 2020. These guidelines are also in line with the Construction Strategy 2020 [4] and the Communication on opportunities for improving resource efficiency in construction [5]. They also form part of the most recent and ambitious circular economy package presented by the European Commission in 2015 [6], which contains legislative proposals on waste to stimulate the EU's transition to a circular economy [7]. The Minimum Environmental Criteria for Construction [2] regulate, among other things, technical specifications for construction sites (art.2.5), concerning those operations that lead to potential environmental pressures, namely: demolition and dismantling of materials, materials used, environmental performance, staffing, excavation and backfilling. Prior to demolition operations, quantities and types of materials that can be reused, recovered, or recycled shall be determined through the following operations:

- identification and risk assessment of dangerous waste that may require special treatment or emissions that may arise during dismantling;
- estimation of the quantities of different construction materials;
- estimation of reuse rates and recycling potential based on proposals for sorting systems during the dismantling process;
- estimation of the potential percentage achievable with other forms of recovery from the demolition process;
- on-site provisioning, and subsequent reuse, of the plant-soil for a depth of 60cm, for the construction of embankments and public and private green areas.

These indications [8] are an integral part of the Italian Public Contracts Code (Legislative Decree 50/2016 and subsequent Corrective Decree 56/2017), art.34 as regards the basic environmental requirements (energy and environmental sustainability criteria) and art.95 as regards the award criteria in the award of the contract [9]. The study, therefore, intended to investigate the hypothetical scenario resulting, in the first instance, from the application of the mandatory regulatory parameters imposed by the basic CAM, as well as to develop the scenario relating to the achievement of the award scores, for the purposes of awarding the contract (art. 2.6 of the DM 11.11.2017).

2. STATE OF THE ART

The Italian residential heritage of the 20th century includes examples of high architectural quality, such as the one realised with the INA Casa Law, in force from 1949 to 1962, thanks to a specially planned economic-qualitative mechanism. Older than this historical period, some examples of settlements, which developed quickly in the Second World War as an immediate response to the housing emergency, are now at the end of their life cycle both structurally and technologically, also of poor architectural quality. The pilot project concerns the demolition and reconstruction of a social housing district in the province of Salerno, dating back to the late 1940s. The buildings are made up of a reinforced concrete load-bearing structure, reinforced concrete and hollow tiles mixed floor and hollow bricks. The structures, although sized before the anti-seismic regulations, show almost irreversible degradation pathologies. The same is true for technological systems and finishing works. For this and similar cases of current construction, the need of demolition and reconstruction "in situ" becomes unavoidable. Until a few years ago, this scenario was characterised by the organisation of the site according to traditional methods, whose demolition phase was characterised by "empty for full" type of metering, which generated a chaotic mixture of waste, delivered to the landfill in an undifferentiated manner (representation of model '1'). This outdated demolition dynamic was also characterised by a particular speed of execution since the resulting materials were disposed of almost at the same time as the demolition operations. Compliance with the

Building CAM [2] requires innovative organisational methods: the storage operations of the materials to be selected and of the sooty ground require further exhaustive layouts of such management. There is a need to find neighbouring areas where to move, deposit and treat the waste materials. Furthermore, the simultaneous demolition and reconstruction must be properly planned according to the possibility of reuse and/or recycling "in situ" of part of the waste material. This strategy would allow the reduction of part of the costs of transport, disposal and delivery.

3. METHODOLOGY

The experimental model, called model '2', is divided into the following phases:

- 1st phase) definition of the dynamics of the demolition and reconstruction process;
- 2nd phase) technological characterisation of the buildings to be demolished (in order to determine the types of materials and the respective quantities by weight);
- 3rd phase) definition of the objectives (basic CAM / rewarding CAM);
- 4th phase) identification of the most suitable demolition techniques and estimation of their economic impact;
- 5th phase) definition of the layouts of the significant phases of the demolition process, with regard to the organisation of the site as well as the possible annexation and use of neighbouring areas;
- 6th phase) development of the time schedule for the demolition site scenario, based on the set objectives;
- 7th phase) estimation of direct costs related to the demolition intervention, materials handling and management of the site;
- 8th phase) preparation of the reconstruction project, in accordance with the qualitative and quantitative parameters of the minimum environmental criteria, with regard to the technical specifications for groups of buildings [10], single building and building components;
- 9th phase) simulation of the recovery/recycling scenario of the resulting materials, as part of the concomitant in situ reconstruction project, through the elaboration of the demolition and construction waste management plan [11] in order to determine the recycling and reuse potential of the resulting materials [12]. This phase is in line with the principles, recommended by current legislation, aimed at minimising the quantities of demolition waste to be sent to landfill [13-15].

The variables taken into account for the development of the model are:

– the organisation of the site, according to the phases of the intervention;
– the execution and management time of the demolition and waste treatment phases;
– the logistics of the selective site, with the annexation of any areas, possibly adjacent, for the storage, selection and preparation of waste materials;
– the technological characterisation of existing buildings and those to be rebuilt, for the estimated amount of potential recovery/reuse of waste materials, depending on their intended use.

The final objective, given the peculiarities of the new organisational approach, is to determine any direct costs changes, deriving from the different organisational and management methods of the scenarios envisaged.

3.1. DEFINITION OF CRITERIA AND TECHNIQUES

From this point of view, the adoption of suitable criteria and techniques for the execution of the demolition phases, according to the methods of selective demolition, i.e. through dismantling, disassembly and/or disassembly of components, in order to differentiate waste by homogeneous fractions, orienting it towards recycling operations [13], in accordance with the shared criteria and technical guidelines for the recovery of inert waste, governed by the Italian legislation in force [11, 12]. Demolition must be carried out in a sequence that is exactly the opposite of the construction sequence, from top to bottom, first of all on the finishes, then on the partitions and curtain walls, in order to achieve the maximum result in terms of resulting materials' selection, and then proceed in succession with the structural elements demolition. One of the most effective demolition techniques is the use of hydraulic grippers and shears, which is advantageous in terms of impact with the surrounding environment and risk reduction, i.e.: reduction of percussion on the building and the ground, reduction of vibrations, noise and dust towards the surrounding environment, reduction of fragments to wheelbarrow size, minimisation of temporary shoring, simplification in the selection of material for subsequent recovery and recycling. The boom of the demolition vehicle will be suitably equipped with a water mist jet system for dust abatement and will be assisted by an excavator for the removal of debris from the work area, for the handling of rubble inside the site and for loading onto trucks for the handling of waste materials. The latter, if already selected during the demolition phase, after the allocation of the appropriate CER code [11], will eventually be prepared for the reuse phase on-site, or, if they require a further selective phase, they will be deposited in a special site area.

3.2. SETTLEMENT DYNAMICS

The dynamic hypothesised for the intervention, of reconstruction in situ, takes up the one conceived for the Complex Urban Redevelopment Programmes of the Municipality of Naples, with the aim of reducing the mobility of the occupants to almost zero. It is divided into successive phases, according to an implementation mechanism that provides for the temporary relocation of the inhabitants to a neighbouring area, called “triggering area”, where temporary housing has been previously installed. The settlement dynamics are as follows [16]:

- first phase: identification of the triggering area, within the neighbourhood or in neighbouring areas;
- second phase: in the case of availability of an “internal” area, the reconstruction of the first lot is carried out directly; in the case of availability of an “external” area, temporary accommodation is installed in which residents can be moved from time to time, based on a rotating mechanism
- third phase: gradual demolition of the buildings and simultaneous construction of replacement buildings with the relocation of the inhabitants through successive phases;
- fourth phase: completion of the external accommodation in the spirit of integration of the neighbourhood equipment and integration into the surrounding area.

Given the peculiarity of this dynamic, the experimental scenario hypothesised takes into account the organisation and management of the demolition phases according to the overcoming of the basic CAM, i.e. the achievement of the rewarding requirements as per art. 2.6 of DM 11.11.2017, useful for the awarding of the contract (art.95 of Legislative Decree 50/2016) [9].

3.3. APPLICATION OF MODEL ‘2’ TO THE CASE STUDY

In order to exceed the basic requirements, i.e. to obtain the bonus requirements, the verification of the model with respect to the case under consideration is structured in the following phases.

3.3.1. 1ST PHASE

Implementation of the dynamics of the demolition and reconstruction work [17]. The intervention has been divided into functional lots (five steps), in order to optimise the size of the temporary settlement complex, defined as the “triggering district”. To this end, an adjacent area was identified, about 350m away from the site area (Figure 1), with an extension of about 2300m^2, in which to install the prefabricated monoblocs (6.05m x 4.9m), aggregated according to housing types congruent with the types of households that must pass through, according to a rotation mechanism. At the end of the demolition and reconstruction programme, the prefabricated monoblocs can be reused in another place, for another building replacement or, as a subordinate measure, they can be reconfigured to perform a different function. The costs relating to this installation, considered to be unchanged for the types of the site under investigation, have not been taken into account in the relative economic quantifications.

Fig. 1. *a) Localization of the trigger area. b) Installation of the triggering quarter.*

3.3.2. 2ND PHASE

Technological characterisation of the buildings to be demolished. To this end, the archival documentation of the public administration was retrieved and analysed, as well as through on-site surveys. On the basis of this information, the nature of the materials and the respective quantities to be subjected to selective demolition were determined.

3.3.3. 3RD PHASE

Organisation and management of the building-site aimed at meeting the minimum environmental criteria or at achieving the rewarding criteria. In order to achieve rewarding requirements, it was intended to act on the following work activities. Increase in the percentage of selective demolition, in order to exceed 70%, by weight, of materials to be sent for reuse or recycling, through operations of disassembly, removal and/or decomposition, of the following architectural elements/materials such as bituminous conglomerate and road foundation of the road network inside the district; external and internal windows and doors; sanitary fixtures and fittings; floor and wall coverings; coverings and screeds; internal partitions; cladding; structure in elevation after setting aside 60 cm of sooty ground for subsequent reuse.

3.3.4. 4TH PHASE

Demolition techniques. For the demolition works, selective techniques have been foreseen for the majority of building structures, excluding only those building systems and/or components characterised by the aggregation of several materials and elements (horizons, screeds, etc.) for which the selection, after demolition, would not have guaranteed a convenient material weight/cost ratio.

3.3.5. 5TH PHASE

Elaboration of the layouts of the demolition phases. Due to the peculiarity of the settlement dynamics, the demolition process is divided into five significant layouts (Figure 2). The demolition phase requires the temporary occupation of a neighbouring area, identified near the site area, where the materials are transported, deposited, and treated according to their final destination.

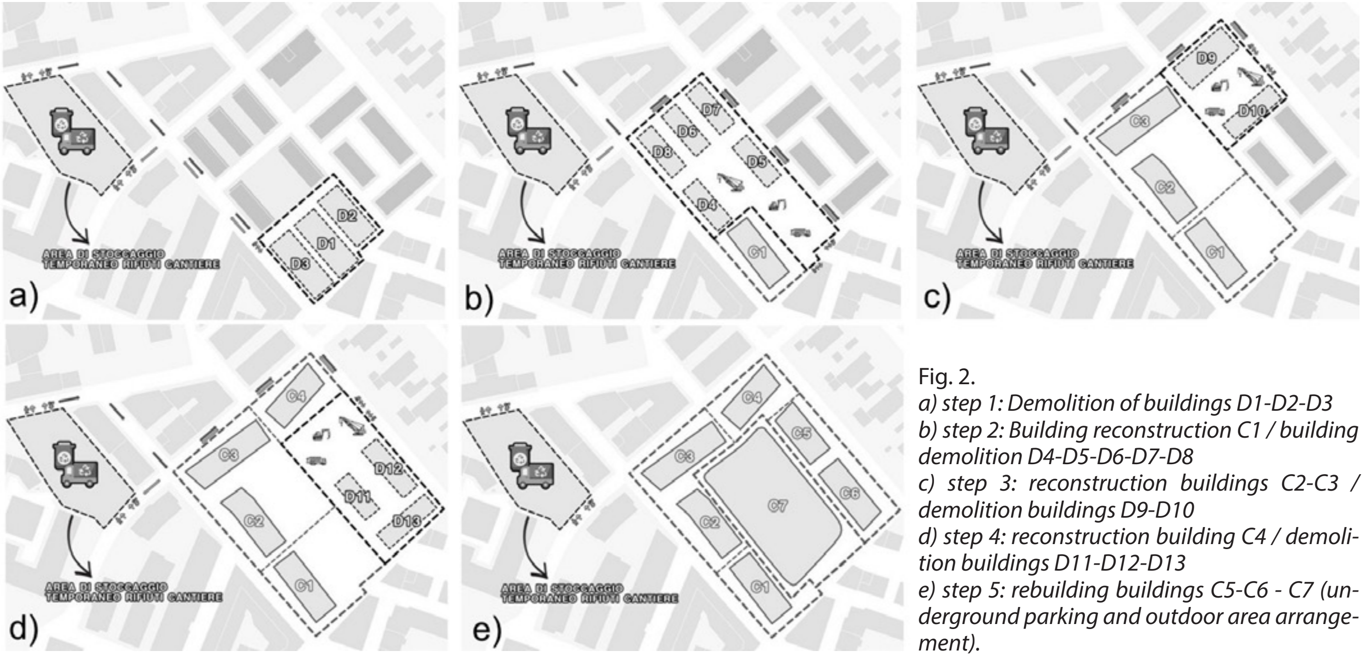


Fig. 2.
a) step 1: Demolition of buildings D1-D2-D3
b) step 2: Building reconstruction C1 / building demolition D4-D5-D6-D7-D8
c) step 3: reconstruction buildings C2-C3 / demolition buildings D9-D10
d) step 4: reconstruction building C4 / demolition buildings D11-D12-D13
e) step 5: rebuilding buildings C5-C6 - C7 (underground parking and outdoor area arrangement).

3.3.6. 6TH PHASE

Chronoprogram development. The chronoprogram of the experimental model ('2' model) shows a duration, of the overall demolition process, of about 70 days (compared to the 26 days estimated for reference model '1', i.e. related to the traditional site).

3.3.7. 7TH PHASE

The estimate of direct costs related to the demolition and management of the site (table 1). The costs of model '2' have been quantified on the basis of the price list of the Campania Region with the exception of the cost relating to selective structural demolition, defined with an appropriate price analysis. These costs amount to a total of euro 902,848, of which euro 675,459 for work, and euro 227,389 for site preparation and logistics. The layouts in figure 3 show the different configuration of the site area, between the traditional model ('1') and the experimental model ('2'), the latter requiring more space for the transformation of materials.

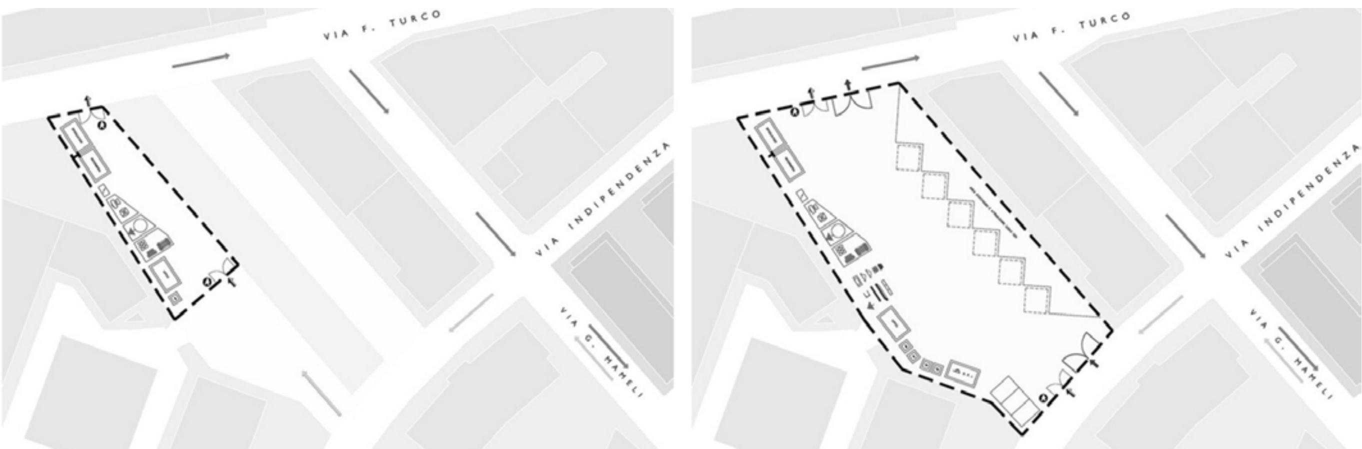


Fig. 3. *a) Perimeter of the annexed area (configuration relative to model '1' - traditional building site). b) Perimeter of the annexed area ('2' model configuration - experimental site).*

WORK ACTIVITIES	QUANTITY		COSTS	
			NON Selective Demolition [0% selection].	Selective Demolition [94% selection]
			MODEL "1"	MODEL "2"
DURATION OF DEMOLITION AND TRANSPORT ACTIVITIES			26 days	70 days
1. CONSTRUCTION SITE PREPARATION / LOGISTICS				
1.0 Rent public land			€ 18 078,00	€ 159 280,10
1.1 Provisional fence			€ 32 004,72	€ 66 676,50
1.2 Monoblocks, WC			€ 1 432,00	€ 1 432,00
Total costs related to site set-up and logistics			€ 51 514,72	€ 227 388,60
2. DEMOLITION AND LANDFILL TRANSPORT	m^3	kg		
2.1 Asphalt removal (road)	906,87	1450987,52	X	€ 14 321,53
2.2 Demolition of road foundation	1133,58	1700376,00	X	€ 7 280,28
2.3 Demolition of fixtures (frames and glass)	35,47	38983,40	X	€ 5 621,62
2.4 Sanitary Removal	-	5130,00	X	€ 1 876,50
2.5 Removal of sanitary ware (tubs)	25,20	4050,00	X	€ 813,60
2.6 Removal of floors (marble tiles)	41,04	23596,85	X	€ 35 703,06
2.7 Screed demolition	164,15	180567,20	X	€ 17 138,90
2.8 Total coverage removal	9,07	27,22	X	€ 16 740,00
2.9 Demolition screed cover	143,63	157987,50	X	€ 14 995,36
2.10 Demolition of partitions (up to 10 cm thick)	322,88	209869,92	X	€ 15 433,51
2.11 Demolition of partition walls (10-15 cm thick)	26,59	17286,05	X	€ 1 830,55
2.12 Demolition of partition walls (15-30 cm thick)	122,69	79747,20	X	€ 5 417,90
2.13 Demolition of infill masonry	1747,44	1223208,00	X	€ 63 187,43
2.14 (A) Demolition of traditional elevation structure	16828,00	20869505,71	€ 283 720,08	X
2.14 (B) Demolition of elevated structure with hydraulic grippers on excavator	12453,47	20869505,71	X	€ 211 160,71
2.15 (A) Transport to authorized landfill (empty for full)	16828,00	20869505,71	€ 279 681,36	X
2.15 (B) Transport to authorised (selective) landfill	12453,47	20869505,71	X	€ 206 968,86
Total charges related to work activities (2)			€ 563 401,44	€ 618 489,82
3. EXCAVATIONS AND TRANSPORT TO LANDFILL				
3.1 Surface humus h.60cm	2885,00	4905180,00	X	€ 6 203,61
3.2 Humus handling and storage for reuse	2885,00	4905180,00	X	€ 19 505,30
3.3 Excavation	7894,00	13419800,00	€ 50 768,78	€ 31 260,24
Total excavation costs			€ 50 768,78	€ 56 969,15
COMPLESSIVE AMOUNT WORK AND FACILITIES (excluding landfill charges)			€ 665 684,94	€ 902 847,57

Tab. 1. *Comparative overview between models 1-2, regarding the estimation of site set-up costs and demolition and transport activities.*

3.3.8. 8TH PHASE

Elaboration of the reconstruction project. The design criteria, expected to meet the minimum basic environmental criteria, can be summarised as follows: maximisation of the passive behaviour of the building envelope by minimising the plant contribution; optimisation of thermal bridges and winter/external heat loss; use of eco-compatible and low CO_2 emission insulating materials; exploitation and control of natural lighting in the interior spaces; exploitation of natural ventilation for summer cooling; use of external materials and finishes aimed at minimising the effect of urban heat island; installation of systems powered by renewable sources for winter/summer air conditioning and domestic hot water production; volumetric reconfiguration in order to optimise the free spaces, unified in an internal square (Figure 4).

Fig. 4. *a) Reconstruction project: view of the entrance from the city to the inner square. b) Reconstruction project: internal view of the complex.*

3.3.9. 9TH PHASE

Estimation of the potential economic viability of the recovery/recycling of demolition materials [12], as part of the on-site reconstruction work. The reference scheme adopted for this phase is as follows:

The first step of phase nine (i.e. scenario 2) foresees the estimation of the cost reduction related to the choice

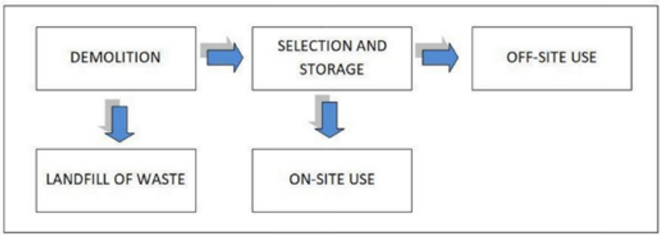


Fig. 5. *Schematic diagram of waste recovery/recycling/disposal dynamics.*

Table 2a	*Starting economic scenario (scenario 1)*				
	model 1		model		model 2
			(basic CAM)		(CAM rewarding)
waste sorting percentage	0%		70%		94%
total demolition costs, waste transport, site logistics	665684,94		723091,98		902 847,57 €
model 2			without reuse SRM (second raw materials)		with SRM reuse
Table 2b	*Comparison of scenarios with and without reuse of MPS (secondary raw materials). The unit prices assumed as landfill charges are national average prices for recyclable (sorted) and non-recyclable (undifferentiated) waste*				
type of scenario			(m^3)	incidence of demolition, transport and landfill costs	
1) economic impact of transport and transfer of the entire quantity of waste materials (differentiated up to 94% by weight)			12453	206 968,90 €	-
2) economic impact of transport and 30% waste disposal, not reusable on site		24% differentiated waste	2988	-	17 928,00 €
	30% rejection	6% undifferentiated waste	747	-	7 470,00 €
Table 2c	*Summary table of costs and percentages of material to be allocated to recovery/recycling operations, in compliance with art.2.5 of the CAMs*				
total cost of demolition, transport, and related site logistics			**902 847,57 €**		**721 276,71 €**
			model 1		**model 2**
CAM satisfaction			**0%**		**94%**
total costs			**665684,94**		**721276,71**

Tab. 2. *Starting scenarios and application of strategies aimed at optimizing the '2' model.*

of reusing waste materials (inside or outside the building-site), resulting from the lower costs of waste transport and landfill of 70% of waste materials (table 2a). Table 2b shows the costs related to waste transport and landfill, in relation to scenarios '1' (traditional construction site, with an undifferentiated transfer of the entire quantity of waste materials) and '2', which is expected to reach the target of 94% (by weight) of materials to be differentiated. In the latter case, the economic savings will be obtained by reducing waste transport costs by 70% of the materials; a further reduction in costs is also recorded with regard to the costs of the landfill, having assumed the ratio of 0.6/1 (according to the average prices of landfill) between the costs of the differentiated fraction (24%) and the undifferentiated fraction (6%).

The economic convenience resulting from the reuse, through recycling of waste materials, makes the experimental model particularly competitive ('2'). Table 2c shows in fact that the scenario '2', which allows the achievement of rewarding scores, regardless of the re-

Table 3a	*Quantity of materials needed for the reconstruction of buildings and internal roads*				
construction of road works			buildings reconstruction		
section	m^3	kg	materials	m^3	kg
bituminous conglomerate	341,275	546040	concrete	7858	19645000
inert	1706	2559000	steel	100,74	785800
Table 3b	*Costs for the purchase of new and recycled material for road foundations and earthworks*				
purchase cost of materials for road foundation and earthworks					
quantity (m^3)	new (€)	recycled (€)	cost difference (€)		
1706	25590	11942	13648		
7894	85255,2	56915,74	28339,46		
Table 3c	*Costs of recycled material in situ for foundations and earthworks*				
on-site recycle					
cost €/d	m^3 / day	m^3 to be treated	days	total cost €	
1200	400	8717	22	26400	
Table 3d	*Summary table of total expenditure for road foundation equipment*				
total expenditure for road foundation materials (inert quantity to buy = mc 823)					
inert new cost (€)				12348	
total cost for recovery/recycling (€)				26400	
total cost (€)				39571	
Table 3e	*Summary table comparing the costs of the scenarios envisaged*				
comparison of the costs of the various options					
new purchase (A)	recycled purchase (B)		on-site recycling (C)		
110845,2	68857,74		39571		
Table 3f	*Summary table of costs and incidence with and without reuse of MPS, relative to the experimental model ('2')*				
model 2	without reuse SRM (second raw materials)		with SRM reuse		
cost of demolition and related logistics	902 847,57 €		721 276,71 €		
incidence reuse of recycled materials	0		-71 274,20 €		
	902 847,57 €		650 002,51 €		

Tab. 3. *Cost trends resulting from the application of the model to the case study.*

use of waste materials inside or outside, is almost equal, economically, to the virtual scenario of the basic CAM (at least 70% selection of waste materials), in Table 2a.

The second step of phase nine (corresponding to scenario 3) foresees the option of recovering/recycling the waste materials in the site, in order to reuse them within the reconstruction project. It is therefore assumed that part of the recovered material will be used, mainly for the roadbeds and backfill works, as these operations, and in particular, all those for non-structural use can be carried out without significant changes to the recycled materials. In fact, the recycled aggregates, milled in different grain sizes, are purified from foreign fractions also through the use of mobile plants, with evident economic and environmental gains [16].

Otherwise, assuming the use of aggregates for the packaging of concrete for structural use with a percentage of recycled concrete, it would be necessary to pass such waste from C&D through a specific treatment plant system that deals with the selection of materials, separation of fine elements, sorting, crushing and packaging of the finished product, with the relative attribution of CE certification.

At this point, the economic savings range of possible solutions is determined. The following table shows the purchase of new and recycled material (table 3):

In this way it is possible to obtain, for the case study, comparing (C) with the hypothesis of repurchase of new material (A) one obtains a saving of 71,274.20 €; while, comparing (C) with the hypothesis of repurchase of recycled material (B) one obtains a saving of about 29,286.74 €.

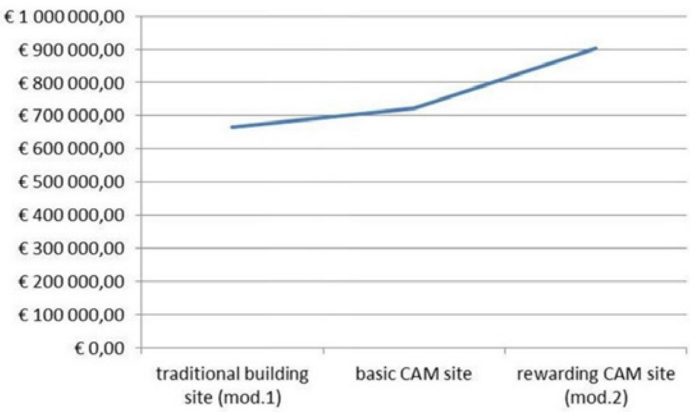
4. RESULTS

The configuration of the 'innovative' site (post CAM) involves a substantial change compared to the 'traditional' one, when the resulting materials did not need to be stored and hinged and therefore, almost at the same time, transported and delivered to the landfill. The traditional site (model 1) requires the annexation of a service area limited to logistics; the experimental site (model 2) requires the annexation of a larger area, not only for logistics but also for the storage and storage, in the medium-long term, of waste materials. The results of the study show changes in costs that lend themselves to subsequent levels of interpretation depending on the type of scenario:

1) demolition without reuse of waste materials
2) demolition with the reuse of waste materials (on-site/off-site)
3) demolition with reuse on-site (as part of the reconstruction project)

Results of scenario 1 (demolition without reuse of waste materials):

The first scenario, which takes into account only the demolition phases, shows a considerable variation in costs, in the transition from the traditional site to the CAM adapted site (Figure 6a). The graph shown in Figure 6b shows the trend of the percentage change in direct costs, in relation to the satisfaction percentage for CAM.



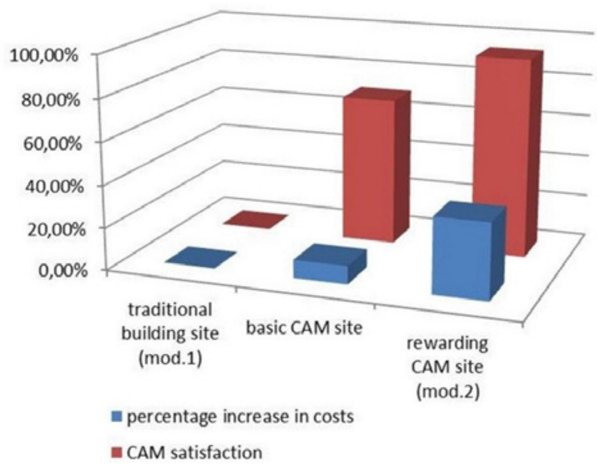


Fig. 6. *a) Graph of demolition cost trends for scenario 1 (without reuse of materials). b) Graph showing the trend of the percentage change on direct costs, in relation to the percentage of satisfaction with CAM.*

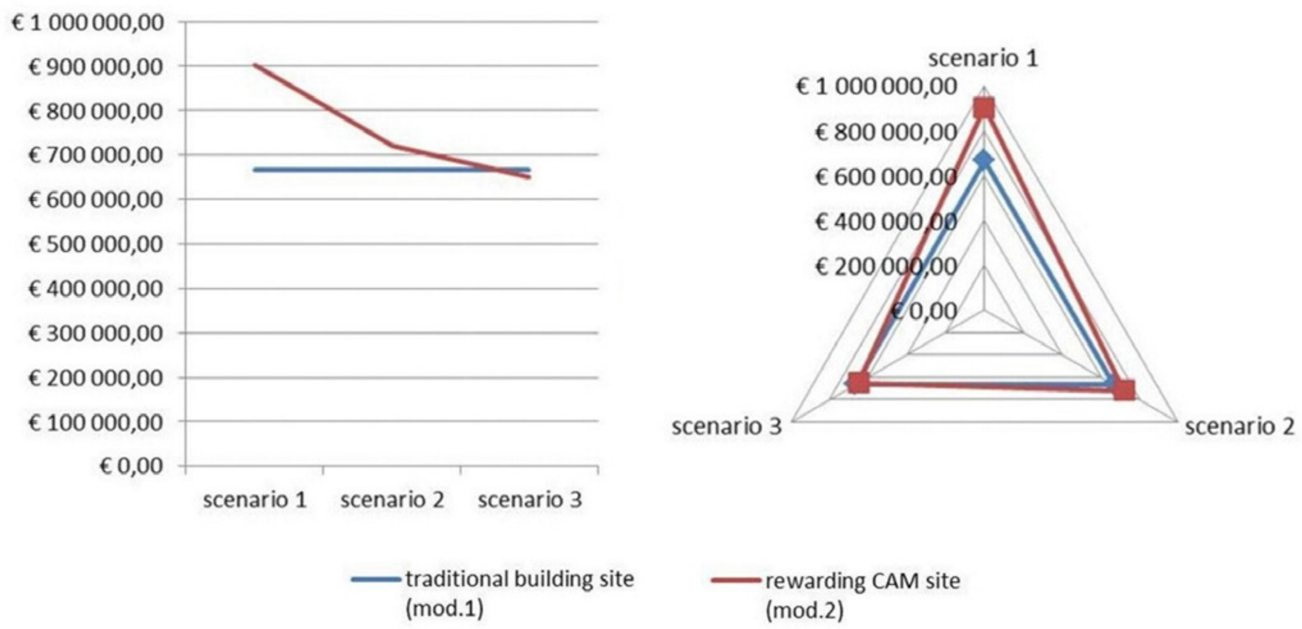


Fig. 7. *Graph show the trend of costs relating to model '2', according to the assumed strategies, as well as the relative variation with respect to the traditional reference model.*

The second scenario presupposes the possibility of using the resulting materials (for now, indifferently de on-site or off-site). The forecast of reuse of waste materials, after the elaboration of the waste management plan according to the current legislation, with reference to model 2, aimed at the pursuit of rewarding CAM, allows an economy, compared to scenario 1, equal to 28% (Figure 7).

The third scenario, which foresees the reuse of recycling materials on-site, after suitable treatment, is the most advantageous profile as it allows to obtain, overall, a reduction in demolition, logistics and transport costs, up to compensate the gap between the costs of the traditional site (mod.1) and the costs of the site prepared for rewarding CAM (mod.2). These results are graphically represented in the graphs in Figure 7 below.

5. DISCUSSION AND CONCLUSIONS

The approaching the end of life phase of some building complexes dating back to the first half of the 20th century makes the problems connected with the demolition and disposal of waste materials more topical than ever. Current legislation requires the drawing up of a plan for the selective disassembly and demolition of the work at the end of its life, requiring compliance with environmental requirements in terms of recycling and reuse of materials.

This approach determines new scenarios regarding the adoption of the most suitable site organisational strategies in order to achieve the set objectives, imposing targeted choices, aimed at the selection of materials, in the demolition process. The expected reduction in 'indirect costs' (i.e. relating to the reduction of environmental impact) translates into an increase in 'direct costs' linked to the demolition process.

The study showed an increase in direct costs (intuitively expected) between the organisation of the traditional site and the organisation of the site prepared for the basic CAM, in the measure of 8.6%, for the achievement of the threshold of 70% recycling or reuse of materials from the demolition process. Exceeding this threshold, in order to obtain the rewarding requirements (to the maximum extent obtainable for the case study), on the other hand, can determine an estimated cost increase of about 35% compared to the traditional demolition site.

However, a scenario of economic compensation through recovery/recycling of on-site demolition waste has been assumed, which would result in an overall economy of 36%, i.e. a negative balance of 1% compared to the traditional site. These scenarios, therefore, make it possible to cancel the economic gap of the experimental site, which is not only adequate to the current environmental standards but organised to achieve the rewarding CAM, to the extent of 24 percentage points, with a view to achieving the rewarding scores when the contract is awarded.

This approach encourages the current growth trends of entrepreneurship in the environmental sector. Many European experiences, in fact, highlight the start of new entrepreneurial activities dedicated to specialised supply chains in the sector, with a consequent reflection on the increase in employment. The study, developed with the objective of quantifying the trend of direct costs, in the transition between the hypothesised scenarios, can evidently be implemented through the estimation of indirect costs, i.e. related to reductions in environmental pressures resulting from the dynamics hypothesised for the development of the experimental model (mod.2). It is evident, in fact, that the latter approach has a lower impact in terms of exploitation of primary resources [18], as well as in terms of reduction of CO_2 emissions [19-20].

Future research perspectives are aimed at defining possible technological scenarios that will allow optimising the reuse and/or recycling of materials, coming from the demolition process, within the on-site reconstruction project, thus defining a technological continuity in the transition 'from grave to cradle', according to the logic of a circular building economy.

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