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IMPACT ON THE ROAD SYSTEM OF MATERIAL HANDLING FOR THE CONSTRUCTION OF MAJOR CIVIL WORKS: THE LAZIO-STRETCH OF ROME-NAPLES RAILWAY

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ABSTRACT: This works appraises the problem of carrying materials for the actualisation of a thoroughfare infrastructure, such as in the case of the Lazio-stretch of the high-velocity Rome-Naples railway.
Should the materials taken from the excavation for the actualisation of the works necessary for the construction of the passage of the railway line prove insufficient, then it is necessary to resort to procurement from quarries.
When quarries that are chosen are also near the track, however, İn terms of the location of the deposits, the extraction activities and the necessity to distribute certain procurements along the whole distance, then recourse to material handling that ineluctably effects the pre-existing road network becomes necessary.
In this way, the material transportation system relies network on whose nodes comprise the operational quarries, the provisional stock piles of the materials and the building sites. Its branches comprise service roads from the quarries to the road networks and all the roads (state, regional, provincial and urban roads).
The urban branches of the network are particularly important on account of the environmental effects cause on the inhabited part of the territory.
The present work analyses:
- the road network used for the transportation of the construction materials for the above-mentioned railway infrastructure;
- the volumes conveyed from the quarries to the building sites;
- the incidence of purchase and transportation costs;
- the effects on the environment in terms of energy dissipation and of diffusion of pollution gases into atmosphere.

1. INTRODUCTION

The realisation of a great civil work necessarily implicates the operations of excavation of the stretch (in gallery and in trench) and of construction (for the portions in relief and in viaduct).

These operations involve the handling of materials from the sites of excavation for the realisation of the work and from the surrounding quarries. In fact, if the materials produced by the excavations are not utilisable again to the goals of the construction of the same work, their removal it is made necessary and their transportation to dumping.

Therefore it is made necessary the provisioning of that material that possesses the characteristics applications for the construction.

As it regards the dumping of the non-fit materials, the choice of the sites is bound to the present dumps on the territory preceded to welcome the materials resulting from the activity of excavation.

The choice of the working quarries from which to provisioning a complex function depending of a lot of parameters:

- the availability of the necessary quantities of materials İn the scheduled time;
- the quality of the materials;
- the distance of the sites of use of the materials from the sites of production;
- the production-costs of the materials (Minds, 1997).

Sometimes it can be convenient to individualise new exploitable sites for the extraction of materials. In fact, in the case of materials for concrete and tarred works, the usable rocks, being enough diffused on the terrestrial surface; even if this diffusion can have meaningful to continental staircase, while it is not always having value if it is gone down to the regional staircase.

It was well known besides that they are not only the geological characteristic to define a rock-deposit, but also the technical-economic conditions and the

actual juridical provisions.

The location of die quarries has to found on the complete analysis of the entire requisite foreseen by the present normative in the regions in which the exploitation activity is carried out. It has to be considering many other factors as the economic efficiency the level of the social system, the ecological-environmental sustainability, the quality of the interested landscape. It owes therefore to found on a job to which collaborates experienced of different fields, from the economy to the geology, to the mining technique, to the ecology, to the hydraulic one, to the management of the land.

If is not possible, for juridical, economic or geology constraints, to open new quarries in the proximity's of the infrastructure to build. It is necessary to resort to the materials already produced in quarries in activity that can be distant in comparison to the places of use of the themselves materials, with the inevitable additional costs for the transport and the problems of pollution owed really to the same transport.

2. NET OF PROVISIONING OF THE MATERIALS TO A LINEAR INFRASTRUCTURE

The transport of materials, necessary to the realisation of a linear work and provisioned by the sites of it extracts surrounding, it generally happens on road and particularly it is effected by trucks.

This transport necessarily burdens on the existing public road-net, since it is rare that a site of extraction is connected with the yard of use or stocking through a devoted road-net.

In this way it is come to constitute a net of transport whose knots are constituted by the quarries of provisioning, from the sites of provisional stock of the materials and from the yards of construction. Moreover the branches are constituted from the roads into the quarries up to the road-net for the different levels of use (government, regional, provincial and urban). The urban branches of the net dress again particular importance for the effects that are induced by the heavy transport on the high-inhabited territory.

It can be recognised then the environmental load that such operation involves. Indeed in terms of trouble to the ordinary road circulation, therefore in terms of energy consumption (varying also according to the typology of the quarry provisioning the stretch) and finally in terms of issue of the gases from the trucks.

As it regards the first type of environmental impact, it is previously of difficult recognition depending on the real situation traffic in the road-net, under conditions of absence of transport of materials to the alone construction of the infrastructure.

It is easier the evaluation of the second type of impact that can appraised in base to the available data on the handling of the materials from the quarries to the sites of use. Likewise for the issue of the gases of unloading for whose evaluation can be considered the runs and the typologies for the materials transportation.

3. THE ROAD SYSTEM IN THE AROUND OF THE ROME-NAPLES RAILWAY

Following analysis makes reference to the problem of the transport of materials finalised to the construction of the Lazio-draw of the high-speed Rome-Naples railway.

The Lazio-draw of the high-speed Rome-Naples railway has beginning near the inhabited area of Saloon, east of Rome, where it is connected to the railway of Tivoli in the penetration toward the city.

, The railway layout continues toward Naples, at first parallel to the Rome-L'Aquila highway, up to Lunghezza, and then parallel divert toward south of the Rome-Naples highway, passing near S.Cesareo, Valmontone, Colleferro, Anagnİ, Ceccano, Castro of the Volsci and Ceprano (League, 1997).

The figure 1 shows the location of the yards of the Lazio-draw of the railway line in examination, as well as the location of the quarries and the yards of stock.

As it can be seen by the figure 2, the road-net of the usable zone for transport of the materials, in the surroundings of the railroad, is constituted by:

- the Rome-Naples highway (A 1);
- the Casilina and Appia roman roads;
- two other main roads;
- some regional roads;
- a lot of secondary roads especially in the north of the railway layout.

For economic and safety motives, the trucks mat transport the necessary materials to the realisation of the work don't run in the highway; on the contrary, they privilege the Casilina road, not few contributing to already weight the ordinary traffic rather congested. The Casilina road, in fact, colleagues all

the small towns that are found between S.Cesareo and Ceprano.

From cartographic surveys of the figure 3, related to the runs of the vehicles and to the activities of the yards, data are obtained, (brought in table 1) related to:

- the railway yards;
- the quarries that supply each yard;
- the quantities of supplied materials, classified in the two great categories {basalt and limestone) as used for the construction of the railway.

In the figure 3, with reference to the road-net interested by the heavy traffic, the

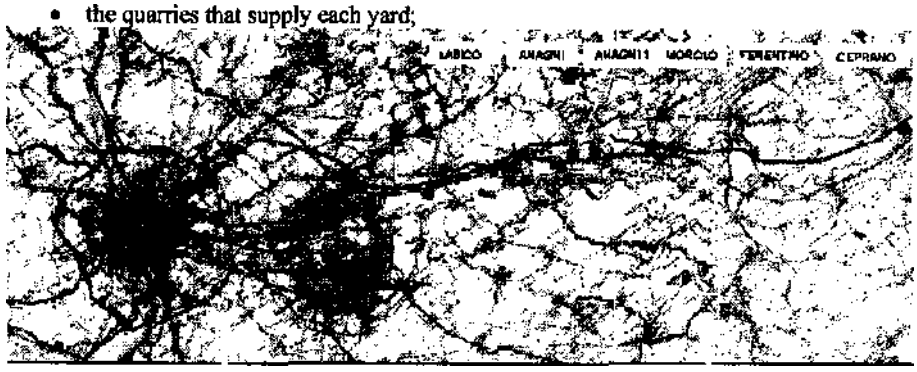


Figure 1 - Layout of roads İn the Lazio Region in the surroundings of Rome with the high-speed Rome-Naples railway and the related yards İn evidence.

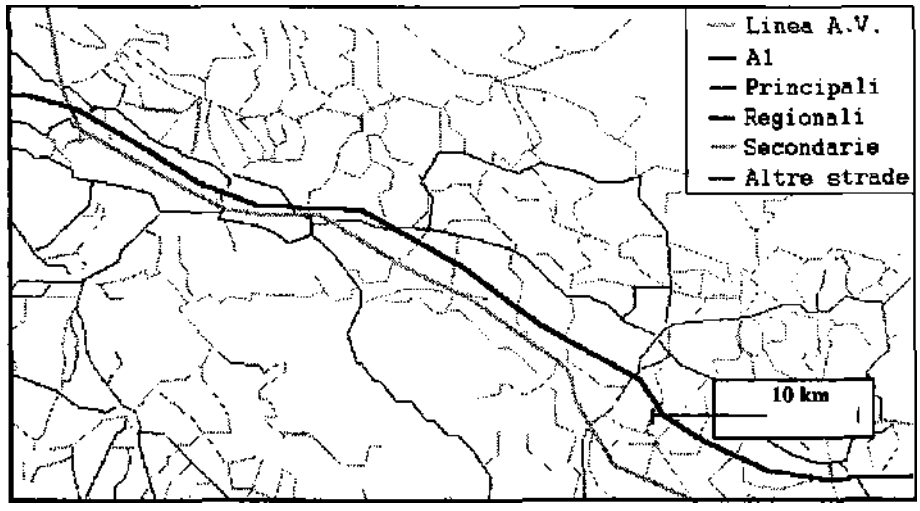


Figure 2 - Typologies of the roads in the Lazio territory crossed by the high-speed Rome-Naples railway.

Table 1 - Energy-environment analyses of the sites of exploitation that provision the yards of the Lazio-stretch of the high-speed Rome-Naples railway.

M	P	L	Q	Y	R	D (km)	S (ioW)	E ($I0^{'3}$MJ)	G (kg)
basalt	Laghetto	lowland	Basalto Laghetto	Labico	r s	21.5 3.2	50	11	407
limeston e	Artena	lowland	Simba	Labico	r 0	5.0 4.0	150	9.8	1,054
basalt	Lanuvio	lowland	Stradaioli	Anagni	r s	44.0 3.0	100	21	814
limeston e	Altena	lowland	Precicchi a	Anagni	r s	21.7 3.8	866	160	6,115
basalt	Laghetto	lowland	Gruppo Schina	Ferentin 0	r s	43.5 8.0	180	58	1,466
limeston e	Segni	lowland	Sic	Ferentin o •	r s	4.9 8.0	1,143	75	8,067
limeston e	Segni	hillside	Schina	Ferentin 0	r s	14.5 8.0	1,143	210	11,106
basalt	Labico	lowland	Stradaioli	Ceprano	r	86.4	30	9.6	244
basalt	Laghetto	lowland	Pennacchi	Ceprano	r	78.9	40	13	326

CONNECTION

M typology of the provisioned material
P place
L location
Q quarry provisioning the material
Y provisioned yard
R type of road crossed by the trucks (r: regional; s: secondary; o: other type)
D distance run from each quarry to the yards by the trucks
S supply of material
E total energy requirement
G total issues of gas from trucks

crossing of the inhabited towns is underlined, as well as the runs from every quarry to the yards served by the same.

With reference to the provisioning of basalt, it is noted that:

• tiie yard of Labico was supplied by Basalto-Laghetto quarry and, therefore, the heavy trucks run on the Casilina road (regional road) and on the inhabited area of S.Cesareo, as well as on a short draw of roads classified as secondary;

• the yard of Anagni was supplied from Stradaioli quarry (out of the map), sited in Lanuvio: therefore, the trucks crossed secondary roads (street of the Five Arcs, Aryan street) and a regional road (Casilina), marginally interesting the inhabited area of Velletri and Artena;

• the yard of Ferentino was used the basalt from the Gruppo Schina quarry, in the site Laghetto, and from the Stadaioli quarry; therefore, the trucks run along the Casilina road, until over Anagni, and along the secondary street until to Morolo;

• the yard of Ceprano was supplied both from the Pennacchi quarry, in the site of Laghetto, and from the Stradaioli quarry; therefore, the trucks run along the Casilina road, up to Ceprano, crossing the inhabited area of S.Cesareo, Frosinone (remaining on the bypass) and Ceprano.

Wim reference to the provisioning of limestone it is in relief that:

• the yard of Labico, was provisioned by the

quarries in Artena: as a consequence the transport of the materials essentially interested the streets of Artena and then the Casilina road;

• die yard of Anagni was provisioned by the caves sited in Segni: as a consequence the transport of the materials interested the bypass of Colleferro before run along the Casilina road to reach the yard to provision;

• the yard of Ferentino was provisioned by the quarries sited in the proximity: as a consequence the transport of the materials involved a limited impact on the road-net because they interested mainly secondary roads;

• the yard of Ceprano was provisioned by quarries sited in other region (Campania) out of the field object of investigation and represented in figure 2 and figure 3.

4. BALANCE OF THE PROVISIONED MATERIALS

Table 1 shows the balance of the materials provisioned for the realisation of the Lazio-draws of the railway line in study.

The geologic nature of the Lazio has not allowed provisioning for basalt from quarries more neighbours to the Rome-Naples railway, in fact, the only caves of the zone are those in the site Laghetto (along the Casilina road) and that in the zone Lanuvio (all near ones in the zone of the Colli Albani) in which the phenomenons are verified eruptive legacies to the activity of the enclosure Tuscolano- Artemi sio.

The location of the existing basalt quarries İs favourable to the provisioning of ballast for the yard of Labico. On the contrary the distance starts to make important for the other yards. In particular the yard of Ceprano is affected, in terms of costs of transport, by the problems related to the great distance from the quarries of provisioning and by the fact that are not lava rocks in the zone an quarries that can furnish the railway ballast.

As it regards the limestone, instead, the discourse is more simplex; in fact, in the whole Lazio, there is abundance of breakthroughs of limestone deposits.

The quarries of such material are numerous and, therefore, the provisioning of limestone, necessary for the works in concrete and for the in relief ones of the viaducts, has been possible beginning from quarries sited around in about 10 km from the yards. Nevertheless, the quarries that were able to supply the demand of limestone had a no-high annual production, varying among 240,000 nw/y from Segni quarry up to 600,000 nvVy from Artena quarry. Insofar the supply of the in demand quantities of material has been reached in more years of production.

In the table 1 the provisioning of limestone related to the yard of Ceprano İs not put İn evidence: as already recalled, it was provisioned by quarries sited in an other region (Campania), running a distance from the yard less that from the Ferentino quarry.

5. EVALUATION OF THE ENVIRONMENTAL IMPACT

The study here developed is finalised to the analysis of the environmental impact of the quarrying activity taking into consideration from it extracts and of the transport of the materials from the exploitation sites to the yards.

As first criterion of evaluation of such impact is chosen to classify, according to their typology, the quarries that provision the railway line in examination.

The classification of the quarries in the two types, of mountain (or better of the type hillside) and of lowland, it is dictated by the different consumption of energy that it involves in the two cases the transport of the materials up to the sites of use.

In fact, quarries exploiting the same type of material are differentiated for the mining methods adopted and for the type of run the trucks when they deliver the quarried material under different topological situations.

If the quarries are mountain quarries, it happen an high energy consumption and a lot of gaseous issues superior the case lowland quarries, without taken into consideration the run of the trucks for the transfer of the material from quarry to the site of destination.

On the following it's put in evidence, therefore, the energy-environmental analysis related to the quarries that supply the railway line of ballast and limestone. The analysis is based on;

- the typology of the quarry;
- the supply of the material application;
- the distance among the quarry and the supplied yard;

- the typology of run completed by the trucks.

It is put in evidence, in conclusion, the global energy requirements for the activities of production and transport of the quarried materials and the gaseous issues that are produced by the same activities. To the purpose of the evaluation of the procedure suggested by Badino (1997) has been used.

As it regards the typology of the quarry it is noticed that all the quarries of basalt are lowland quarries. Concerning the quarries of limestone, those of Artena and of Ferentino are similar to lowland quarries; but the quarry of Segni is of the type of hillside quarry.

As it regards the classification of the quarries in the two types (lowland and hillside), it İs put in evidence that the energy consumption (associated to 1 kg of material) clearly results greater for the materials running from mountain-quarries in comparison to that running from lowland-quarries ($30.9*10^{-3}$ MJ/kg for the first one against 2.295*10" 3 MJ/kg for the second).

As it regards the typology of road interested by the transport of the materials, this engraves in the environmental impact involving an increase of the pre-existing traffic on the roads. Moreover, when it also interests the street-nets of the towns, also an increase of the atmospheric pollution (coming from the gases issued by the trucks) and of acoustic pollution (constituted by noise and vibrations) occurs.

The acoustic pollution İs of difficult to quantify İn energy terms.

As it regards the distance of transportation, the environmental impact İs still expressible in energy terms:

- the transport of the materials at a distance of 10 km behaves an energy consumption which can be estimated equal to of about 1.8 times that related to the only productive activity;
- the transport to distances of 50 km involves an increase of energy consumption up to 5.3 times that related to the only productive activity;
- the transport up to distances of 80 km behaves an increase of energy consumption up to 7.9 times that related to the only productive activity.

It has taken into consideration the total energy consumption, related to the phases of production and transport, concerning each quarry provisioning the Rome-Naples railway.

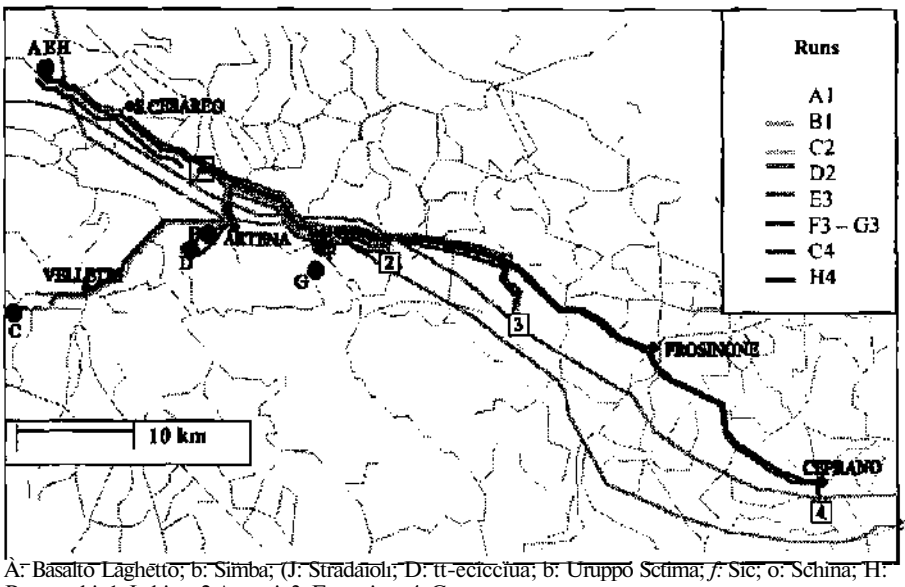
From last, the value of the total issues of gas produced by the trucks during transportation of the quarried materials has been taken into consideration.

In such a way it has been examined the environmental effects, both to global staircase (effect shuts, hole of the ozone) both to regional staircase (acidification, eutrophisation, smog), respectively estimating the quantities of the issues of CO2, CFC11, SO2, NO3, C2H4, express as equivalent kg (Minds, 1997).

From table 1 it is inferred that, also being sited to a reasonable distance from the yards (globally inferior to 25 km), the quarries that provision of limestone the yard of Ferentino lead to energy consumption more than those that supply of basalt the yard of Ceprano (sided to around 80 km of distance).

This analysis is demonstrative of the incidence of the transport of the materials, as on the other hand it was logical to expect from a simple evaluation of the importance of the runs that the trucks have to complete for bringing the whole quantity of in demand material to destination.

Another evident consideration comes from the comparison of the energy consumption related to the typology of the quarries. For the two quarries of limestone that supply the yard of Ferentino, for the same supplied quantity of materials, a clean difference emerges İn terms of global energy requirement and total issues of gas. It is imputable also to the greatest distance of route that İt happen in the case of a hillside quarry as put in evidence in figure 4.



A: Basalto Laghetto; b: Simba; (J: Stradaioli; D: tt-ecicciua; b: Uruppo Sctima; *f:* Sic; o: Schina; H: Pennacchi; 1: Labico; 2:Anagni; 3: Ferentino; 4: Ceprano.
The runs, suitable with different colours, are evidenced by codes alphanumeric location-allocation.
Stradaioli quarry (C) is found out to 5 km of distance by the edge of the figure.

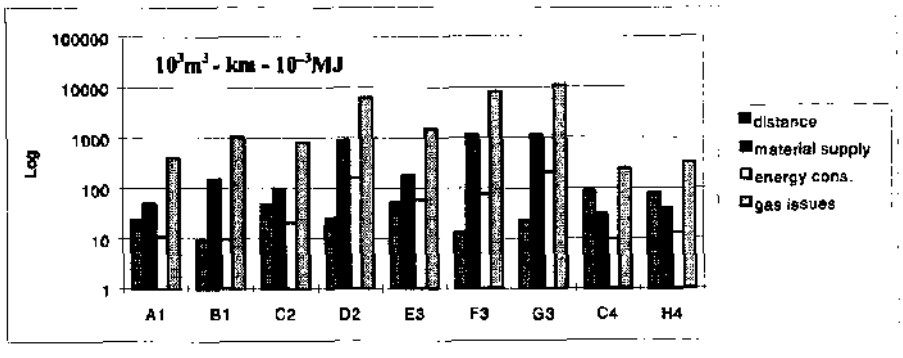


Figure 4 - Environmental impact of the provisioning of materials with reference to the various typologies of quarries {lowland and hillside), and ofthe materials (basalt and limestone). Material supply (ItPnw) and distances from quarries to yards (km) in comparison with energy consumption (10^{-3}MJ) and of issue of gas (kg).

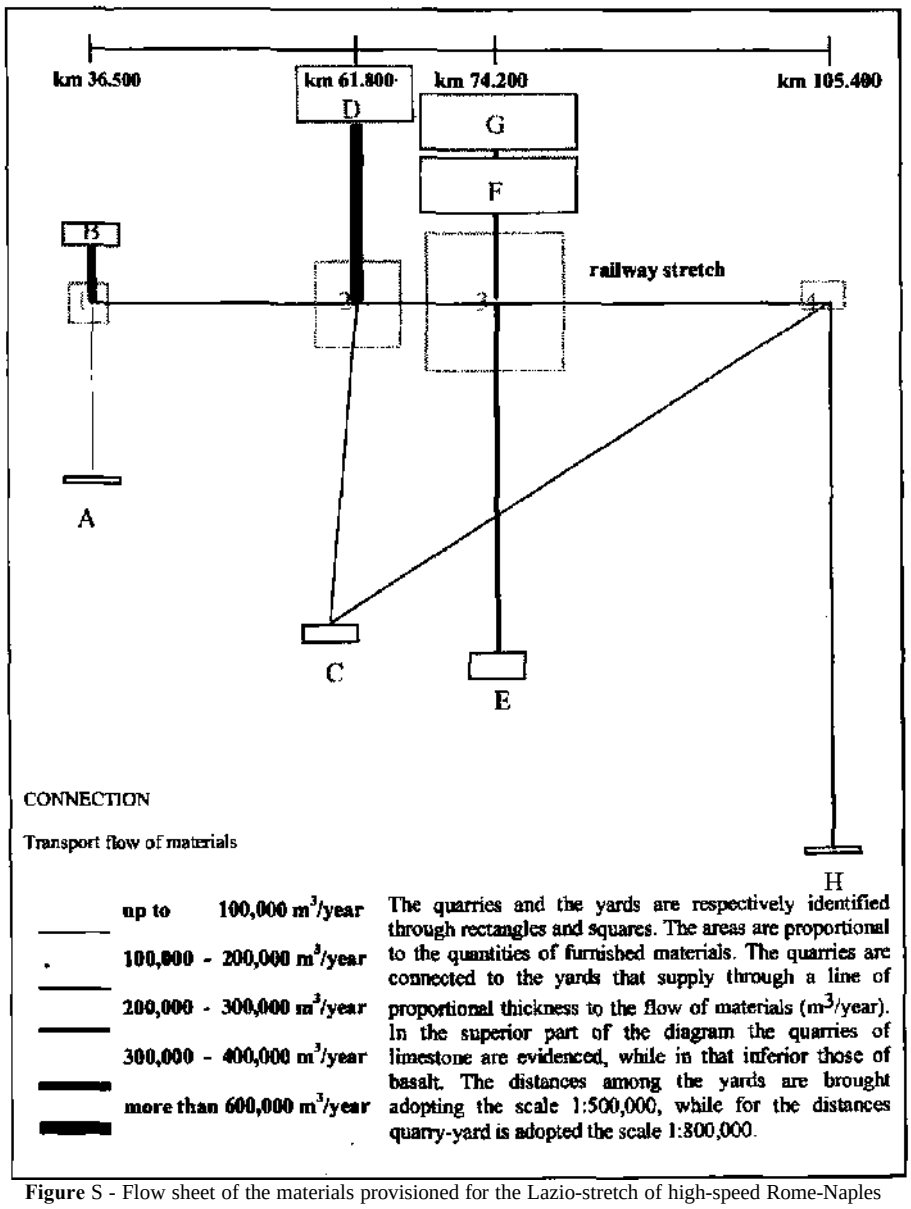


Figure S - Flow sheet of the materials provisioned for the Lazio-stretch of high-speed Rome-Naples

6. Conclusions

The study has shown the enormous incidence, İn terms of environmental impact of the transport from a quarry, on the materials need for the construction of a linear infrastructure-

Thé environmental impact of the transport of the materials from quarries to yards can subsequently be underlined by the analysis of flows, taking into consideration the locations of the quarries and of the yards (figure 5).

In energy terms, the high incidence of the transport of the materials is caused by the absence of a basalt quarry in the nearest of the railway line.

It has been put in evidence that, taking into consideration the energy consumption and the issues of gases for unity of product, the lowland quarries clearly result favourite in comparison to mountain quarries.

It has not been possible to quantify the alteration of die landscape owed by the exploitation activity and the trouble created to the towns by the traffic of the trucks.

Neither İt has been possible to appraise, in environmental terms, the operation of dumping of the deriving materials from the excavations of the civil work and of the discards of quarrying. In fact, the creation of areas to destine such materials generally involves a strong alteration of the landscape.

In relation to this last problem it deserves a citation of the initiative of the Val di Cembra quarry: the discarded material of porphyry, to confer in dump, İs transformed in a material usable in the realisation of in elevation works for highway or railway. In such a way the areas destined to exploitation and dumping are reduced; and, as a consequence, the issues due material handling and transportation are reduced (Callegari, 1996).

It can be concluded whether to appraise the provisioning of the materials is always necessary to take into consideration the concepts of economic efficiency, of environmental efficiency, of minimisation of the issues and of correct management of the geo-resources.

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