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Sustainability Analysis Based on Emissions Saving for Competitive Maintenance and Rehabilitation Practices

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Abstract

Although roads are preponderant in terms of extension and usage, airports and air transport entail a prominent part of emissions and energy consumption worldwide. There is a need for improving airport pavements construction and maintenance practices in order to limit greenhouse gasses and set environmental standards towards the development of more “sustainable airports.” Since environmental impact assessment of major projects is becoming mandatory in many countries, various researches are attempting to evaluate environmental impacts of different pavement materials, technologies or processes over the airport service life. There is a need to measure and describe different aspects of airport pavements sustainability to support these efforts. This paper analyzes emissions saved in reusing and valorizing existing in situ soils through a cement stabilization for improving the bearing capacity of the runway cleared and graded area and/or constructing new sub-base pavement layers. The analysis evaluates emissions due to equipment and materials comparing them with the supplying of large amounts of aggregates from nearby quarries to build granular layers. A case study of a major Italian airport is finally provided. Results show the eco-efficiency of improving pavement management practices adopting energy efficient treatments on airports. Furthermore, eco-saving factors could represent a new and innovative feature to be added in process of evaluating different strategies and investments in an Airport Pavement Management System.

Keywords: sustainability, life cycle assessment, carbon footprint

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1. Introduction

Environmental certifications and eco-labels are already available for a great variety of buildings and industrial products. Similar procedures and approaches are being developed to design and assess sustainability and sustainable transport infrastructures. Rating systems and tools are becoming popular and more commonly used to assess the sustainability of transportation infrastructure assets, materials, processes and asset management programs. Although roads and road pavements are preponderant in terms of extension and usage, airports and air transport represent a consistent part of the transportation related emissions and energy consumption.

Several standards, regulations, and reports on the environmental impacts of aviation have been released by the main air transport authorities (ICAO, FAA, EASA, etc.) in the last years. Moreover, the ISO standards 14000 [1] provide guidelines to assist organizations in establishing, documenting, implementing, maintaining and continually improving their management of eco-design as part of an Environmental Management System (EMS). However, the regulations mainly focus on emissions due to the exhaust system of aircrafts' engines, noise reduction policies, air traffic management strategies, and ground maneuvering efficiency. Nevertheless, airports and terminals daily consume a huge amount of materials and primary energies to carry out maintenance, new constructions, and future developments on the airport infrastructure, both air and land side. Policies oriented towards the reuse of non-renewable resources, the recycling of materials, and the optimization of processes for reducing energy consumption, should therefore be implemented into the airport management systems.

Several Japanese airports, mainly built on artificial islands from reclaimed land, have adopted environmental friendly strategies in the last decade in order to reduce emissions produced by new construction, maintenance, and standard daily operations. Countermeasures embraced are not only related to aircraft engines and noise but also take into account the whole surrounding environment. Waste recycling and reduction, optimization of lighting systems, use of clean fuel, preservation of sea environment, temperature adjustment in terminals, cogeneration plants to provide heating water and power, sustainable exploitation of renewable resources, are just some of the several uncommon ways for reducing greenhouse gases and energy consumption towards the realization of a "green airport" (i.e., Hong Kong International Airport, one of the busiest airport in the world, saved 5,875 tons of equivalent CO2 in 2009-2010 by adopting sustainable policies [2]). Following this example, both European and American association are showing interest in sustainable airport practices. The Green Sustainable Airports (GSA) association in northern Europe and the Clean Airport Partnership in the United States [3] represent a clear example of the growing interest in reducing the airport environmental footprint.

1.1. Objective

The present paper analyzes the impact of using pavement maintenance and rehabilitation practices that limit the amount of greenhouse gases emissions and embodied energy consumed through the reuse and valorization of in-situ soils. In particular, the environmental impacts related to cement and/or lime stabilization of in situ soils are evaluated. Since a huge amount of non-renewable resources and funding are used every year for new construction and maintenance practices on airports, calculation of the emissions produced in a certain design/maintenance strategy is very important. It could represent a step forward for selecting the "right" material. Similar results in terms of cost and performance can be achieved using more eco-efficient alternatives, which consume less energy and produce less pollution. The paper provides a methodology to quantify the eco-efficiency of low carbon/energy construction and maintenance practices and discusses how this methodology can be used for managing airport pavements. The practicality of the approach is illustrated through a case study of a major Italian airport.

2. BACKGROUND

2.1. Reusing and Valorizing In-Situ Soils

Material recycling and non-renewable resources saving surely represent two of the main activities for achieving sustainability in airports since the wide area involved for new construction, maintenance, and rehabilitation. Recycled materials, both belonging from waste and already available on-site, have the potential to reduce emissions and energy consumption produced by construction and maintenance operations. Furthermore, reusing, recycling and valorizing, would reduce the hauling distances and related emissions for material supplying. On the other hand, emissions and energies involved in the processes for converting waste and disposable material into new and effective resources should be therefore carefully analyzed. A life-cycle approach is usually adopted for the purpose. Converting materials at the end of their service life into useful resources for following applications can enhance the usual cradle-to-grave approach into a more comprehensive cradle-to-cradle (also known as Open Loop Production) assessment [4] where the end-of-life disposal step for the product is a recycling process. In this way the environmental impacts of products are minimized by employing sustainable production, operation, and disposal practices.

In particular, stabilizing in situ soils with cement or lime allows reducing materials supplying and new soil consumption, limiting in the meanwhile soil handling across the construction site and increasing productivity. Furthermore, the reuse and the valorization of existing soils limit waste materials and the amount of new virgin aggregates required. Moreover, using cementitious materials as hydraulic binder for soil stabilization, for instance, allows the enhancement of soils mechanical properties making them able to meet the structural requirements usually demanded from a foundation (or sub-base) layer or particular airport safety areas. Enhancements achieved through stabilization include better soil gradation, reduction of swelling potential or plasticity index, improvement in durability and strength, increase of the shrinkage limit, reduction of clay/silt-sized particle, and raise the resilient modulus [5]. Even if existing in situ soils are not appropriate to be stabilized as they are, recycled materials can be added afterwards in order to create a suitable mixture to be treated. The benefits of reusing in situ soil are, in this way, enhanced by the eco-advantages of valorizing waste materials, saving landfills and energies for the disposal.

Moreover, M&R activities in airports have to be carried out in a very limited amount of time in order to avoid a reduction in the airport capacity and a consequent increase in traffic delays. Usually, no more than 4 to 6 consecutive hours are weekly available without air traffic when dealing with main airports. Delaying or postponing maintenance activities can therefore results in a significant loss of revenues. The following section proves that stabilizing in-situ soils increase the productivity and reduce the intervention time if compared to providing virgin aggregates from outside.

2.2. Environmental Assessment of Paving Materials

The methodology adopted takes into account carbon emissions to develop an environmental assessment of M&R strategies for increasing the bearing capacity of the runway cleared and graded area (CGA) and constructing foundation layers of airport pavements. Emissions due to the equipment adopted during construction operations, were converted into carbon equivalent emissions [6] to compute a project carbon footprint for each alternative.

Carbon footprinting consist of the calculation of the total amount of greenhouse gasses (GHG) emitted for a product. All the processes, and their related emissions, involved for transforming the initial raw material into the final ready-to-use product, can be considered into the carbon footprint assessment. These eventually can also include hauling, storage, lying down, and disposal. A single footprint considers the six GHGs identified by the Kyoto Protocol [7]: carbon oxides (COx), methane (CH4), nitrous oxide (N2O), hydrofluorocarbon (HFC), perfluorocarbon (PFC), and sulfur hexafluoride (SF6). These gasses absorb infrared radiation and can therefore affect the climate when resent in the atmosphere. For simplification purposes, the six gasses are combined together into a single index, the carbon footprint's unit measure: the equivalent carbon dioxide (CO2e). Converting a certain greenhouse gas into an equivalent unit of carbon dioxide can be done by multiplying the amount of that GHG by its Global Warming Potential (GWP) on a specific time interval, usually 100 years [8].

The GWP is the measure of the global warming produced by a GHG trapped into the atmosphere for a specific time interval (20, 100, or 500 years). Its potential of warming up the planet is compared to the CO2 warming potential, usually assumed equal to 1. For instance, the GWP related to the methane is 25, nitrous oxide is 298, hydrofluorocarbon (HFC-23) is 14800, and sulfur hexafluoride is 22800 [9]. Even if accurate chemical analyses are available on almost every pollutant in the atmosphere, carbon footprint analysis still represents a challenging task. A comprehensive database of emissions produced on every single process for converting raw material into the final product, is still far to be completed.

However, it is common practice to limit the calculations to emissions related to the fuel consumption, whatever fuel type is adopted in the various processes (gasoline, diesel, electricity, methane, etc.). In the following sections equipment and construction processes were investigated for assessing the carbon footprints of reusing and valorizing in situ soils. A case study of a major Italian airport is provided at the end.

Setting the boundary conditions is a key part of the life-cycle assessment; the paper especially focuses on the carbon footprint of construction activities and related machines. Including the manufacture of raw materials using a cradle-to-gate approach (or a cradle-to-grave approach) still represents a challenging task and was not taken into account in the following paragraphs. The only way to correctly quantifies emissions related to the manufacture of raw materials is knowing exactly the quantity of pollutant produced in each phase of an extremely complex and articulate process. Emissions coming from bitumen, for instance, should include: emissions due to oil extraction, transportation from the oceanic platform to the refinery with boats or barges, refining of crude oil into bitumen, transportation and storage in depots, etc. Since this varies considerably depending on the production method and fuel adopted, several literature sources analyzed provide a range of values that is anything but closed. That is why there is a strong need for a unique and universally adopted database on emissions due to raw materials manufacture.

2.3. Equipment and Construction Emissions and Embodied Energies

Several pieces of equipment, currently used in airport construction sites, were analyzed to provide a calculation of the emissions. Soil stabilizers, spreaders, scrapers, rollers, graders, dozers, excavators, loaders, and trucks, were investigated for identifying and quantifying emissions produced in M&R activities.

Two different treatments were analyzed and compared: (1) stabilizing in situ soils with hydraulic binders and (2) supplying new virgin aggregates from a source outside the construction site. The total amount of motive-power, and therefore the fuel consumption, was estimated. The main source of pollution in a construction site can in fact be related to the engine exhaust system of the equipment. However, the real quantity of instantaneous fuel consumed is hard to estimate; indeed, a great variety of stochastic aspects could affect the assessed value: working experience and behavior of the operator, inability to directly measure the instant fuel consumption, multiplicity of available engines and brands, etc. Therefore, the methodology adopted and the simplifications made in the analysis are hereafter explained.

First, the analyst should identify the number and the type of machines utilized to carry out the work. Then, the time each piece of equipment is going to be used should be estimated; e.g., considering the productivity data stated on the technical specifications of the machines. Obviously, during a real site application the total amount of equipment adopted is conditioned by the useful time the contractor has to finish up the specific work.

For the purpose of the paper, a sample work process was adopted. The specific pieces of equipment, their quantity, and usage hours chosen are summarized in Tables 1 and 2 for the two treatments. The calculations were conducted as follows:

1. Engines from the major manufacturers were analyzed to identify the fuel consumption to carry out a specific action (soil stabilization, grading, rolling, etc.).
2. A procedure to convert the calculated fuel consumption into emissions produced was used [10].
3. The total amount of equivalent CO2 was computed for each equipment model based on the type and amount of fuel consumed.

2.4. Converting fuel consumption into carbon emissions

Technical specifications of the different engine types, obtained directly from manufacturers, provided curves for relating the BSFC (Basic Specific Fuel Consumption, g/kW·h of fuel), with the engine rotation speed (revolutions per minute – rpm). Torque and power curves determined the relation between the nominal power supplied by the engine (Kilowatt – kW), and its rotation speed. The amount of fuel consumed was then calculated using the equation 1. Obviously, different amounts of fuel could be computed depending on the engine rotation speed and the nominal power supplied in a certain specific instant. Thus, it was assumed that the engine was run at the rotation speed that provided the maximum torque while carrying out the work. This circumstance is desirable from an environmental standpoint; in fact, the BSFC of an endothermic engine is next to the minimum value at the maximum torque because, at that running speed, the engine is proven to be more efficient.

$$F\ [l] = BSFC\ [g/(kW \cdot h)] \cdot P\ [kW] \cdot T\ [h] \cdot 1/\gamma\ [l/g] \qquad (1)$$

Where:
F = fuel consumed,
BSFC = basic specific fuel consumption,
P = engine power when the rotation speed provides the maximum torque,
T = operation time to carry out a specific activity, and
γ = density of the fuel (diesel density $\approx$ 0.85 kg/l).

The U.S. Code of Federal Regulations [11] provides values for carbon content per gallon of gasoline and diesel fuel:

- Gasoline carbon content per gallon: 2,421 grams
- Diesel carbon content per gallon: 2,778 grams

The Intergovernmental Panel on Climate Change guidelines [9] for calculating emissions inventories require that an oxidation factor be applied to the carbon content to account for a small portion of the fuel that is not oxidized into CO2. For all oil and oil products, the oxidation factor used is almost equal to 0.99 (99 percent of the carbon in the fuel is eventually oxidized, while 1 percent remains un-oxidized) [10]. Moreover, to calculate the CO2 emissions from a liter (or gallon) of fuel, the carbon emissions are multiplied by the ratio of the molecular weight of CO2 (m.w. 44) to the molecular weight of carbon (m.w.12): 44/12.

- CO_2 from a gallon of gasoline = 2,421 grams x 0.99 x (44/12) = 8,788 grams = 8.8 kg/gallon = 2.3215 kg/liter
- CO_2 from a gallon of diesel = 2,778 grams x 0.99 x (44/12) = 10,084 grams = 10.1 kg/gallon = 2.6639 kg/liter

Finally, the fuel consumption was multiplied by the specific amount of equivalent CO2 produced in the combustion of a liter of diesel (equation 2) in order to find out the total quantity of emissions due to the machines used for the two specific interventions.

$$CO_2 \text{ emissions } [g] = F\,[l] \cdot \alpha\,[g/l] \qquad (2)$$

Where:
α = specific amount of CO2 emitted during the combustion of a liter of diesel = 2,663.9 g/liter.

The following section presents a maintenance project on a major Italian airport. Environmental savings due to the re-use and valorization of in-situ soils were computed applying the methodology previously described.

3. Case Study

Every runway should be contained symmetrically within a safety strip. The surface of the strip is usually made of grass and should be clear of any obstructions such as ditches or fence posts, and be of sufficient strength so as not to cause structural damage to an overrunning aircraft. Ground emergency vehicles should be supported as well. For a Code 4 runway, the strip must extend at least 150 meters either side of the runway centerline and at least 60 meters beyond the end of the runway including any stopway (according to the ICAO specifications [12]). The portion of the STRIP within a distance of at least 75 meters from the center line of the runway (Clear and Graded Area – CGA) should be so prepared or constructed as to minimize hazards arising from difference in load bearing capacity to aircrafts which the runway is intended to serve in the event of a veer off. In particular, the sinking of the nose gear for the critical aircraft in overrun must be smaller than 15 cm in order to avoid its collapse.

The strict requirements imposed by assuring safety in airports impose the enhancement of the bearing capacity in certain areas of the STRIP where the existing soil is weak. Replacing the existing soil with high-quality aggregates for a certain intervention depth constitutes the main procedure commonly adopted to modify the soil strength. Since airports entail vast intervention areas, a huge amount of quarry aggregates has to be provided. A great amount of emissions is therefore produced due to materials extraction, hauling, and placement.

The following section presents and quantifies the environmental savings due to the reusing and valorization of in-situ soils through a cement and/or lime stabilization treatment for achieving the standard requirements within the CGA. Comparisons between the two alternatives of intervention, as well as sensitivity analyses to the hauling distance, are finally provided.

3.1. Carbon Footprinting of Enhancing the Bearing Capacity of a Runway STRIP

This section presents the calculations for computing the carbon footprints of two processes for enhancing the bearing capacity of particular airport areas: stabilizing in situ soils and supplying new virgin aggregates from outside. Several assumptions were made in the analysis:

- A Code 4E runway was taken into account according to the ICAO standards.

- The only area to be treated was the CGA due to the major requirements on the bearing capacity.
- The productivity of the equipment was assumed equal to the one indicated in the technical specifications provided by the manufacturer.
- Engines were assumed to work in a range next to the maximum torque condition, maximizing in this way the engine efficiency and the fuel consumption.
- Different intervention thicknesses were adopted for the two M&R methodologies: 20 cm of in-situ stabilization and 30 cm of virgin aggregate replacing. The difference is due to the higher performance of a cement stabilized soil.
- The spray of the bituminous emulsion for protecting the layer was not considered in the carbon analysis being common operations for either methodology.
- The hauling distances for the soil stabilization method are almost equal to zero, being everything solved inside the construction site and relatively small quantities have to be moved.
- The work shift time was equal to 6 consecutive hours per working day. Some activities may overlap during the time schedule.
- The daily productivity was equal to almost 3,000 m^2/day for the in-situ stabilization and almost the half for the virgin aggregates supplying. Stabilizing in-situ soils allows to finish the construction activities in almost half of the time (90 vs. 180 working days, respectively)

Bringing new aggregates from the quarry to the construction site makes the hauling distance become a major entry in the emissions list; a distance equal to 20 km from the quarry site was assumed for the calculations. However, a sensitivity analysis was provided at the end.

3.2. CGA In-Situ Soil Stabilization

The working procedure adopted can be summarized as follow:

1. initial scraping for assuring a smoother ride and grass removal;
2. spreading of the cement powder on the upper surface of the soil;
3. in-situ mixing of soil and cement (or lime), eventually adding water;
4. grading, compaction, and hydro-seeding.

The machines used are: a scraper, a dozer, a spreader, a soil stabilizer, a grader and rollers (both tamping and pneumatic). The operating times for each machine to carry out the work on a lane are indicated in Table 1 together with emissions.

The total amount of materials involved in the construction process was considered to determine the environmental impacts, as already discussed in the previous paragraphs. A 1.5% of cement (by weight of dry soil) was added for stabilizing the soil. Considering a stabilization depth of 20 cm, the total amount of soil to be stabilized over an area of 274,400 m^2 is equal to 54,880 m^3. Therefore, the amount of cement needed is almost 1,481.76 t (considering the unit weight of the soil equal to almost 1,800 kg/m^3).

The amount of water needed to reach the maximum Proctor density was not considered in the analysis because both, its environmental impact is very small (0.29 kg/ton of CO2e) and the total amount is strongly variable with the relative humidity conditions of the site. A distance of 2 km was considered from the storage to the construction site in order to compute the emissions due to the transportation of the cement powder for refilling the spreader. A truck was supposed to consume 1.0 liter of diesel every 3 kilometers when travelling on roads (trip to/from the quarry) and 1.0 liter every 1.5 kilometers when travelling on yard tracks (trip to/from the storage site).

Table 1. In-situ soil stabilization – emissions

Machines*							
**equipment considered are standard types and medium performance models*	Working shift time [h]	N°	BSFC @maximum torque [g/kWh]	P @maximum torque [kW]	Total Fuel Consumption [liter]	Carbon Footprint CO_2e [kg]	Percentage of the total emissions [%]
Scraper	2	1	205	145	6,295	16,768.54	8.3
Dozer	4	1	214	120	10,927	29,108.73	14.6
Spreader	1	1	215	135	3,073	8,186.83	4.1
Soil stabilizer	3.5	1	208	420	32,375	86,243.06	43.1
Grader	5	1	210	95	10,562	28,135.61	14.1
Roller 1 (tamping)	1.5	1	215	135	4,610	12,280.24	6.1
Roller 2 (pneumatic)	2	1	215	90	4,098	10,915.77	5.5
Hydro-seeding	1.5	1	200	90	2,859	7,615.65	3.8
	Hauling Distance [km/truck]	N°	BSFC [km/l]		Total Fuel Consumption [liter]	Carbon Footprint CO_2e [kg]	
Truck to/from the storage site (2 km)	≈ 400	1	1.5		≈ 270	719.25	0.4

	TOTAL	**199,973**	**100 %**

3.3. Supplying of Virgin Aggregates

The working procedure adopted can be summarized as follow:

1. initial scraping for assuring a smoother ride and grass removal;
2. soil digging for a depth of 30 cm;
3. loading trucks for getting out the previously excavated soil to the storage site;
4. grading and compaction of the subgrade;
5. unloading trucks coming from the quarry with new virgin aggregates;
6. laying down and grading of the high quality aggregates;
7. final compaction and hydro-seeding.

The machines used are: a scraper, excavators, trucks, loaders, a grader and rollers (single drum and pneumatic). The operating times to carry out the various activities on the STRIP are indicated in table 2 together with emissions.

The total amount of material was obtained considering an intervention depth of 30 cm. The total volume of soil to be removed is therefore equal to 82,320 m^3 and at least the same amount of new virgin aggregates is required. In order to compute the number of excavators and trucks required for carrying out the work, some productivity consideration needs to be made.

If an excavator with a bucket capacity of 1.5 m^3 and a cycle time (loading and unloading) of 20 seconds is assumed, then it can provide 4.5 m^3 of soil into the trucks every minute. Considering the truck loading capacity equal to 12 m^3, then the excavator can load the truck in almost 4 minutes (3 minutes for loading and 1 for maneuvering). Therefore, it can be assumed a productivity of 180 m^3/h for each excavator (a double productivity can be supposed for the loaders).

The numbers of trucks that should serve an excavator is a function of the hauling distance to/from the storage site and to/from the quarry. In the following calculation a hauling distance of 2 km and 20 km was assumed respectively to/from the storage site and to/from the quarry. It is therefore assumed that virgin aggregates were already transferred from the quarry to the storage site before the construction activities began.

Therefore, 5 trucks were supposed to serve an excavator considering a cycle time (loading soil – 4 mins; hauling to storage – 5 mins; unloading soil – 1 min; loading aggregates – 4 mins; hauling to construction site – 5 mins; unloading aggregates – 1 min) of almost 20 minutes.

Table 2. Supplying virgin aggregates – emissions

Machines*							
*equipment considered are standard types and medium performance models	Working shift time [h]	N°	**BSFC** @maximum torque [g/kWh]	P @maximum torque [kW]	Total Fuel Consumption [liter]	Carbon Footprint CO$_2$e [kg]	Percentage of the total emissions [%]
Scraper	3	1	205	145	18,439	49,120.97	8.7
Excavator	3	1	205	145	18,884	50,305.63	8.9
Loader	4	2	215	120	43,708	116,434.90	20.6
Grader	5	1	210	95	17,955	56,271.23	10.0
Roller 1 (single drum)	1	1	215	135	6,146	16,373.66	2.9
Roller 2	1.5	1	215	90	6,146	16,373.66	2.9

(pneumatic)							
Hydro-seeding	1	1	200	90	3,812	10,154.21	1.8
	Hauling Distance [km/truck]	N°	BSFC [km/l]	Total Fuel Consumption [liter]		Carbon Footprint CO_2e [kg]	
Truck to/from the quarry (20 km)	43,200	5	3	72,000		191,802	34.0
Truck to/from the storage site (2 km)	6,480	5	1.5	21,600		57,541	10.2
					TOTAL	**564,376**	**100 %**

3.4. Comparison between the Two Alternatives

Table 1 and 2 clearly show the eco-advantage of stabilizing in situ soils if compared to supply new material from outside (almost 65 % of emissions saved). Besides the time saved for carrying out the work, the main eco-advantage is due to the less materials handling. In particular, hauling to/from the quarry and to/from the storage site is the main responsible for the higher carbon footprint (almost 44 % of the total amount for the “new-aggregates” alternative). Moreover, besides trucks used for hauling, material handling with loaders constitutes a major entries into the emissions list accounting for almost 20 %. On the other hand, transportation emissions due to the in-situ stabilization alternative accounts for less than 1 % of the total amount of pollutant produced. Obviously, soil stabilizer machine has the main environmental impact within the alternative #1, being the most used machine equipped with the biggest engine.

It can be noticed that emissions related to transportation in alternative #2 are almost equal to the whole emissions of alternative #1. Therefore, in order to investigate the influence of transportation on the total emissions produced, a sensitivity analysis was conducted by changing the hauling distance to/from the quarry and to/from the storage site. Considering the distance between the construction site and the quarry, for instance, it is noted that the transportation influence on the total amount of emissions seems to have a logarithmic trend, growing up faster for hauling distance smaller than 20 km and slowing down afterwards.

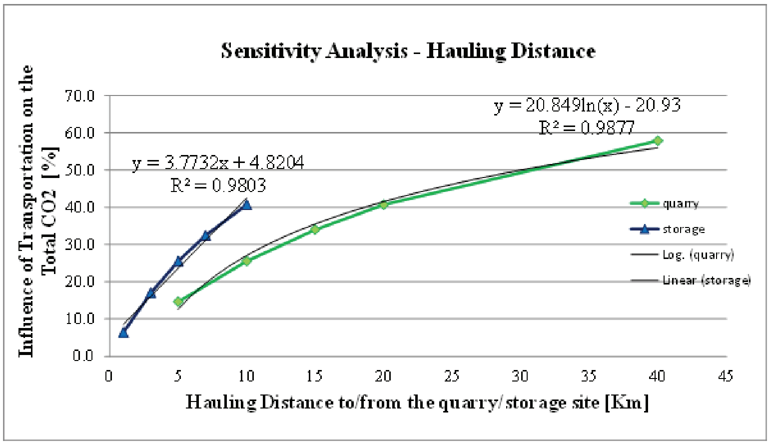

Fig. 1. Influence of transportation on the total amount of emissions produced

4. Conclusion

The paper proposed a novel methodology to assess the carbon footprint of M&R activities on airports. A comprehensive Airport Pavement Management System should include these aspects into the decision-support process in order to develop plans and strategies that consider not only cost and performance, but also the environmental impacts of the actions.

The paper presented a generic method for computing emission and embodied energies and carbon footprint assessment of two maintenance alternatives for achieving standard requirements on airport safety areas. In particular, stabilization of in situ soils represents a great opportunity for contractors, companies, and airport authorities for reducing their environmental impacts while enhancing the bearing capacity of soils and building foundation layers for airport pavements (up to 65 % of emission saved). The paper shows that the soil stabilization method uses the equipment for less time and consumes less virgin aggregates, thus, providing a considerable eco-advantage in terms of emissions produced and energies consumed.

Although the proposed methodology is considered a step forward compared with current practice, the analysis could be improved by adding other variables and analysis processes. For instance, the use of recycled aggregates resulting from a nearby construction site could be investigated in order to evaluate the eco-saving on the total amount of emissions produced. Moreover, other techniques currently available for road construction practice should be analyzed and compared. The aim would be to define a low carbon M&R procedure (maintaining the same performance of a standard pavement), to be used in current practice in order to achieve sustainability on airports in an additional way.

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