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Environmental impact of Building Construction Projects in Northern Europe
Impatto ambientale nei progetti di Building Costruction nel Nord Europa

The concept of environmental impact in general refers to any influence that affects the environment. Usually when discussing about environmental impact in the context of construction industry the emphasis is on pollution and living conditions of fauna and use of material and energy.
The key role in reducing environmental impact is played by careful preliminary planning and skilled labour. Preliminary planning is a way to affect the amount of waste by reducing loss. The significant role of workmanship results and is manifested through the use of suitable tools and working methods. The authors have developed "Environmental Index for Construction Sites (EICS)" method which is used to measure and monitor the environmental impact of a single site. The five categories comprising EICS are 1) information management, 2) waste management, 3) material management, 4) energy use and 5) emissions.

Il concetto di impatto ambientale in generale si riferisce ad un qualsiasi elemento che influisce sull'ambiente. Di solito quando si discute dell'impatto ambientale nell'ambito dell'industria delle costruzioni l'enfasi è sull'inquinamento, sulle condizioni di vita della fauna e sull'uso di materiali ed energia.
Il ruolo chiave nella riduzione dell'impatto ambientale è incentrato su di una attenta pianificazione preventiva e sulla manodopera qualificata. La pianificazione preventiva è lo strumento per diminuire la quantità degli sprechi attraverso la riduzione delle dispersioni energetiche e di materiali. Il ruolo decisivo della manodopera si attua e si manifesta attraverso l'uso di attrezzature adeguate e di metodi di lavoro.
Gli autori hanno sviluppato un "Indice Ambientale per i Cantieri di Costruzione (EICS)" che è un metodo sviluppato per misurare e monitorare l'impatto ambientale di uno specifico cantiere. L'EICS comprende cinque categorie che sono 1) Gestione delle Informazioni, 2) Gestione degli sprechi, 3) Gestione dei materiali, 4) Uso dell'energia, e 5) Emissioni.

Keywords*:* environmental impact; construction industry; raw materials; waste management; construction materials; energy consumption; Environmental Index for Construction Sites (EICS); emissions; material efficiency; site conditions; environmental management system

Parole chiave*: impatto ambientale; settore delle costruzioni; materie prime; gestione dei rifiuti; materiali da costruzione; consumo di energia; indice ambientale per cantiere (EIC); emissioni; efficienza dei materiali; condizioni del sito; sistema di gestione ambientale*

1. INTRODUCTION

When evaluating the environmental impact caused by built environment the focus is usually on the usage of buildings. This is justified as the biggest environmental load is caused during that period in the form of energy consumption. The construction and demolition phases are often ignored. However the construction phase should also be put into focal point as there lies significant savings potential and it is a less studied field. Also, this phase has considerable impact on the environment too. The contractors are not well aware of the impact caused to the environment by their actions. This is due to the difficulty in assessing that impact. Meanwhile environmental awareness is rising on other sectors. (Hämäläinen, 2010).

The EICS team has developed an easy-to-use tool for construction sites for monitoring the impact of an individual site. The purpose of this tool is to raise environmental awareness and improve approach. Additionally small and medium-sized contractors are able tackle the challenges related to environmental conservation and in the same breath enhance their business.

The authors have studied construction related energy and environment issues from various viewpoints. Education and training-wise the emphasis is usually put on training the management. However, significant positive influence may be achieved through employee training. As the legislation and requirements for better energy efficiency tighten increasingly, better skilled labour is needed. Careless workmanship will eventually result in e.g. condensation and mold issues. As a counter measure to these problems-to-be we need down to earth methods to prevent indirect environmental impact.

2. EMISSIONS

The common emissions of construction work are dust, noise and vibration. Dust protection is often one verifiable target. In practice, negative pressure and separation walls are necessary in renovation work. Vibration and noise are more difficult to prevent or reduce, but by providing information, it is possible to decrease inconvenience to and negative reaction from the neighbours.

Dust control	• Dust partitioning is tight and marked, and areas are negatively pressured if needed • Porous materials and others sensitive to dust, such as mineral wool and ventilation components, are shielded • Dust prevention is addressed on site roads • Shielding of the environment is taken into account when doing exterior painting, plastering, sandblasting, etc.
Chemical storage	• Chemical storage is clearly marked and lockable • Small chemical storage containers are in basin
Hazardous waste storage	• At renovation sites, hazardous waste storage is clearly marked and locked
Fuel and oil tanks	• Tanks are secured from falling • Tanks are either double-walled or placed in tub or barrel
Emergency preparedness	• Preventive equipment for oil and chemical accidents is provided (at a minimum, e.g., oil-absorbing peat), and its location is clearly marked • Guidelines for oil and chemical accidents are placed near the preventive equipment

Table 1. EICS acceptance criteria for emissions and handling of hazardous waste

Many local laws and regulations guide the prevention of emissions and the handling of hazardous waste. By taking preventive action, it is possible to avoid potential risks. Legislation sets minimum requirements for environmental operations. However, even these minimums are not always achieved at construction sites, and therefore, some issues for which the letter of the law is not always met were included for EICS evaluation. These issues are shown on table 1.

3. MATERIAL EFFICIENCY AND WASTE MANAGEMENT

The aim of material handling in sites is to transfer materials efficiently and to avoid damage. By storing materials appropriately, unnecessary waste may be prevented. In the Nordic climate, autumn and winter are especially problematic and can bring problems for the storage of some materials. Figure 1 describes means for improving material efficiency in contractor's operations.

Figure 1. Focal points of improving material efficiency in three categories. Design, procurement and production. The common factor for each category is proper materials handling. (Mäkelä 2013).

Construction sector exploits vastly natural materials with none or only a low degree of processing. The environmental impact may be divided into five main categories; Extractive industry, building product industry, construction, use of building and demolition. Each of these steps of material life cycle consumes energy and natural resources and in addition produces waste. The construction sector is a major producer of waste, being responsible for approximately 25 % of all waste produced in Finland. Typical construction and demolition wastes in Finland are mineral waste (1 300 000 tons), wood (250 000 tons), metal (100 000 tons) and other landfill waste (250 000 tons). Without demolition or mineral wastes the amount of waste are 5-10 kg/m3 in construction sites.

Storage areas	• Storage procedures are clear, and workers have been briefed on delivery and unloading processes • There is only one material per material pile • Those materials that are sensitive to moisture are sheltered from rain and moisture (also ventilated) • It is easy to manoeuvre inside the storage areas • Materials in the storage areas are easy to view
Installed components	• Finished building products are shielded to avoid dents, sparks and spatters, especially windows, glass partitions, flooring, edge of routes, furniture, frames, and doors
Material waste and waste prevention	• Clearly unnecessary material loss is not noted in the waste containers • Waste recycling is arranged on the site • Materials are generally purchased in specified lengths and/or in set forms • Materials are primarily stored in interior spaces

Table 2. Material efficiency and waste management issues in construction sites.

4. ENERGY CONSUMPTION AND CONDITIONS ON CONSTRUCTION SITES

Unnecessary energy consumption is both economically and environmentally unreasonable. Site heating is the biggest consumer of energy in Scandinavian setting. The main purpose of energy efficiency measures is to keep heat inside the envelope, while still allowing adequate ventilation. To boost ventilation dehumidifiers and fans should be used in certain conditions, especially in the autumn. Unnecessary need for additional drying should be minimised by closing off interiors from rain and snow. Unnecessary lights and idling machines should also be noted. Basic means of conserving energy on-site are described in table 3.

Air sealing	• Openings are sealed in conditioned spaces • Rain water, leachate and snow are prevented from entering the structure
Heating, temperature and other energy use	• Interior temperatures are under 21 °C • Temperatures in the site office and restrooms are between 18 and 23 °C • No superfluous exterior lighting is on during the day, and unoccupied interior areas are not lit • Power tools are not running idle • Car heating systems are in use in winter
Drying and ventilation	• Relative humidity is under 60 %

Table 3. Means of on-site energy conservation.

During construction, there are certain temperature and relative humidity requirements due to extended concrete curing time in cold conditions. Unnecessary wetting of concrete and other elements should be avoided. A certain temperature range is also required for establishing productive working conditions. However, providing heat when there are large air gaps is a waste of energy resources. This is significant especially in the frosty conditions of a Finnish winter.

In Finland, the energy used for construction and the production of construction materials constitutes approximately 8 % of total energy use. This construction sector energy use is composed of a 4 % share from building material manufacturing, a 3 % share from ground transportation and a 1 % share

from building site operations. The concept of energy usage should include all stages starting from extraction of natural material through construction to completed building. Along must be included indirect factors such as consumption of fuel and other energy sources.
The total energy consumption on building site varies a lot. In the case studies the total energy use were in Uppsala 63kWh/m2 (Hatami 2007). It means approximately 21 kWh/ m3 In Sweden the consumption is divided: 35% heating (district heating), 18% lighting, 27 % site offices, 3 % cranes, 18 % others (tools, containers, fans). In Finland the energy use in case study was measured as district heating 55%, heating by gas 14%, lighting and other equipment 21 %, drying 6%, site office and rest rooms electricity 3% (including heating) and crane 1 %. The total energy consumption on selected Finnish case studies is described in table 4.

Location	Volume	Construction time	Total energy consumption
Case 1, Hyvinkää Finland	6300 m^3	6/2009-6/2010	54 kWh/m^3
Case 2, Tampere, Finland	5308 m^3	1/2010-1/2011	18 kWh/m^3
Case 3, Tampere, Finland	11590 m^3	11/2009-1/2011	22 kWh/m^3
Case 4, Tampere, Finland	10363 m^3	11/2009-11/2010	26 kWh/m^3
Case 5, Valkeakoski. Finland	13200 m^3	11/2009-12/2010	20 kWh/m^3
Case 6, Tampere, Finland	6519 m^3	3/2010-2/2011	25 kWh/m^3
Case 7, Tampere, Finland	22500 m^3	8/2010-4/2012	48 kWh/m^3
Case 8, Tampere, Finland	16461 m^3	8/2010-1/2012	45 kWh/m^3

Table 4 . Energy consumption on housing sites (Cases 1-6 questionnaire, cases 7-8 measured on sites)

In a Swedish case study almost half of the total electricity is consumed during the framework and over half of total electric consumption is used during the indoor phase. (Hatami 2007) The energy use of cranes is quite small amount of the total energy use of building site. In a Swedish case study cranes used about 7440 kWh energy in a building site. In Finland, in a case study the total energy use of a site office in Tampere was 1 % (7680 kWh/year). The division between different forms of energy use in a case study is shown on figure 2.

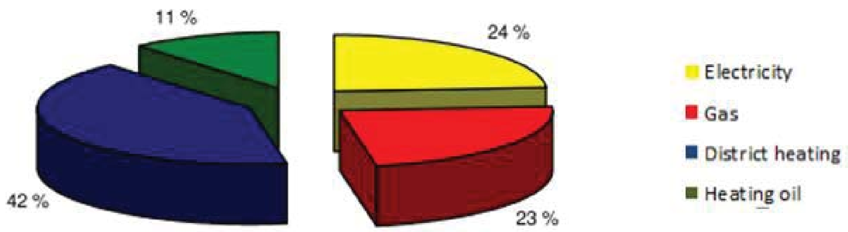

Figure 2. Distribution of energy use on construction site. (Case study, Hämäläinen2012)

It is important to know the demand for heating power on a site. Too small heating power causes damages in concrete structures and too high power increases the costs. On the basis of heating power and target, the heating system is chosen. In optimal case the heating system can be different during the frame work and the inner work.

District heating is often the cheapest method in Finland and it is practical to start to use it as early as possible. In general district heating system is feasible when there are some floors ready in place. District heating fans are often put in place at the end phase of framework and the beginning of the indoor work. On the other hand, the intensity of district heating is not usually high enough for heating the whole building. Oil and gas heaters are used to top-up the capacity deficit of district heating. (Hämäläinen 2012).
Usually, at frame phase liquefied petroleum gas or oil is utilized. Liquefied petroleum gas heaters are light and small relative to the heating power. Gas heaters can be placed only in a room where the amount of ventilation is high enough. Usually the power of gas heaters on a site is 25-150 kW.
Light fuel oil heaters are suitable for heating of the wide spaces like industrial halls, office premises and stores. Usually, it is used at a frame phase and the heating power is forceful. Oil heating produces carbon dioxide and water vapour, but the amount of water is much smaller than when using gas heating. Light fuel oil heaters are also suitable for drying of the building. (Hämäläinen 2012)
Electric heating is quite expensive method and suits best for special heating. In a Finnish case study were disposed costs of different heating methods. The weekly costs of alternative methods including energy, equipment and workforce were: district heating 1,5e/m2, oil 1,8e/m2, gas 1,9e/m2 and electric heating 2,3e/m2 (Hämäläinen 2012).

5. DECREASING ENVIRONMENTAL IMPACTS IN CONSTRUCTION SITES

5.1 ENVIRONMENTAL MANAGEMENT SYSTEM

The research presents an environmental management system for small and medium-sized contractors. The proposed solution consists of i) a general part, ii) forms and checklists, iii) guidelines and posters, iv) a process model, v) signs, and vi) an environmental index of the construction site. The system was developed as a part of action research effort where several workshops with company people were arranged for the system structuring and its testing. The research comprises observations and data from these workshops and system implementation.
The scope of the system covers the typical environmental impacts of construction. Environmental regulations and ISO 14001 standards are the basis of this system. However, the general level presentation of the standard has been modified to be more suitable for small and medium-sized contractors.
The developed EMS system and its elements portray the changing construction management profession under impacts of changing regulatory context. However, in small companies it is particularly important that guidelines are given only for real need and as shortly as possible. Otherwise they don't implement the system or its elements. Implementing phase started with four workshops of over 200 participants at different locations. The implementation at different companies was supported by consultants. They visited the companies three times, and each visit took half a working day.
Environmental management system is part of an organization's management system used to develop and implement its environmental policy and manage its environmental aspects (ISO 14001). The participants wanted to include mostly very practical components in the EMS.

5.2 ENVIRONMENTAL INDEX FOR CONSTRUCTION SITES

The "Environmental Index for Construction Sites (EICS)" meter has been developed based on literature research, legislation and action research. The result of the study is an index tool for evaluating the impact of a site. The tool is included with an observation guide and a form. The main interest lies on materials handling, energy usage, emissions and information management. The observations are recorded on specific form. Based on these form a statistic is created and analyzed with a diagram. The five categories comprising EICS are 1) information management, 2) waste

management, 3) material management, 4) energy use and 5) emissions. (Hämäläinen 2010)
Each category is assessed on the basis of a number of "OK" and "not OK" evaluations. The item of observation may be, for example, a skip, a dust shield, a weather guard, an oil tank or a working method. Waste sorting in the workplace is a typical example of a monitored item. All observations are recorded (table 1). Finally, the sum of all the "OK" evaluations is calculated and divided by the sum of all evaluations, expressed as a percentage (Teriö and Kähkönen 2011). Thus, the environmental index is described by formula (1).

Environmental index = "OK" evaluations / ("OK" + "not OK" evaluations) x 100 (1)

The purpose of the research and development effort of this study was to devise an environmental management system for 15 small and medium-sized construction companies. The practical goal, as stated by company people, was to present a "toolkit", which allows a contractor to minimise environmental impacts. Other aims were to increase the environmental awareness and commitment to reduction of environmental impacts among the participants. The aim of the research was to clarify characteristics of the EMS in this context and find relevant content to it.

Measurement can be performed either once per site or regularly. If it is repeated, the recommended frequency of observation is quarterly or monthly. However, there is no need to check all the documents so frequently. If observations are performed regularly, then those information management items that have been deemed "OK" can be omitted from the continuing observations. Alternatively, it is possible to perform observation during certain project phases such as framing, roofing and interior work, although in this case it may be challenging to follow improvements. The company whose sites are being evaluated must decide the observation frequency itself.

6 FURTHER STUDIES

6.1 ENERGY USE PLANNING MODEL (EUPM)

The importance of energy-saving in different areas has increased in recent years and will continue to be a major research and development area on sites. Real estate in energy issues has been studied extensively, but the energy consumption on sites has been paid very little attention. Field studies show that the energy is wasted in sites in large quantities. Energy savings potential in construction sites is great.

A study should be performed on construction sites by observing heating methods, weather guards and structural drying. It has been noticed that there is much need for simple information about work conditions such as temperature and humidity. A model is needed for calculating the heating and concrete curing efficiently and economically.

6.2 BUILS UP SKILLS FINLAND II

The Build up Skills Finland Roadmap concluded that nearly all construction sector employees could benefit from some type of further training and that energy issues should be included as a cross-cutting theme in all curricula of both basic and further education. The need for short-duration precision training was especially evident. To address the identified barriers, gaps and needs, the Roadmap suggests three broad themes and measures: Development of learning and knowledge, dissemination of know how & verification, and supporting the development of knowledge.

The overall motivation of the project is to increase the number of the skilled construction workers, thus facilitating the attainment of ambitious energy efficiency targets on Finland's construction sites. The approach is very practice oriented and focuses on training and learning on construction sites

Company:	Measurer:
Site:	Date:

	ITEM	OK	SUM	NOT OK	SUM	%
Information management	Organisation and distribution of responsibilities					
	Plans and monitoring					
	Information on worker notice board (action plan, contact address, sorting guide, rescue plan)					
	Restriction of the area and arrangement of information board, site plates, and traffic signs					
Waste management	Waste pallets and containers (marking and sorting)					
	Workplaces and work groups (sorting of primary waste type)					
	Transfer and handling of waste (number of containers and routes)					
Material handling	Material storage (rain, moisture, ventilation)					
	Structure shielding (spatters, sparks, dents)					
	Material losses (waste, recycling, pre-cut materials)					
Energy use	Sealing openings (windows, doors and stairways) during the cold season					
	Drying and ventilation (relative humidity < 60%)					
	Heating (temperature < 21 °C in the winter time, when the construction site is heated)					
Emissions	Dust control (partitioning, negative pressure, working conditions)					
	Chemical and hazardous waste storage and oil tanks					
	Emergency preparedness (guides, instruments, marking)					
		SUM		SUM		

$$\text{Index} = \frac{OK}{OK+NOT\ OK} + \text{OK} =$$

Corrective actions	Schedule	Responsible person	Corrected

Table 5. EICS monitoring checklist

and in environments allowing practical exercises.

The specific objectives of the action are:

- Identify and document today's best practices of energy efficient construction
- Improve the teaching of construction workers, by preparing new teaching material to be used by teachers, preparing a scheme for training teachers, and arranging pilot training to test the approach
- Improve the training of workers on construction sites, by producing education materials and new methods, preparing a scheme for training "change agents", and arranging pilot training of the change agents
- Ensure the connections with the operating environment and relevant other initiatives. Call for Proposals 2012

The project is managed by Motiva Services, a subsidiary of Motiva Oy which is an independent and nationally active expert and service organisation in energy and material efficiency. Tampere University of Technology has strong theoretical and practical expertise in construction, building physics and renovation. Work Efficiency Institute is a research and education organisation specialising in sustainable construction, energy efficiency and renewable energy, and will provide the leadership in the preparation of teaching methods and materials and training of teachers.

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