CHELSEA CENTER FOR RECYCLING AND ECONOMIC DEVELOPMENT
UNIVERSITY OF MASSACHUSETTS

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Lifecycle Assessment Study Guardrail Offset Blocks:

Recycled Plastic, Steel, and Pressure-Treated Wood Blocks

August 2000

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Chelsea Center for Recycling and Economic Development
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The Chelsea Center for Recycling and Economic Development, a part of the University of Massachusetts' Center for Environmentally Appropriate Materials, was created by the Commonwealth of Massachusetts in 1995 to create jobs, support recycling efforts, and help the economy and the environment by increasing the use of recyclables by manufacturers. The mission of the Chelsea Center is to develop an infrastructure for a sustainable materials economy in Massachusetts, where businesses will thrive that rely on locally discarded goods as their feedstock and that minimize pressure on the environment by reducing waste, pollution, dependence on virgin materials, and dependence on disposal facilities. Further information can be obtained by writing the Chelsea Center for Recycling and Economic Development, 180 Second Street, Chelsea, MA 02150.

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Glossary

AZCA	Ammoniacal Copper Zinc Arsenate	PCB	Polychlorinated Biphenol
C&D	Construction and Demolition	PCP	Pentachlorophenol
CCA	Chromated Copper Arsenate	PET	Polyethylene Terephthalate
CO_x	Carbon Oxides	PM	Particulate Matter
HDPE	High Density Polyethylene	PS	Polystyrene
LCA	Life Cycle Assessment	PVC	Polyvinyl Chloride
LDPE	Low Density Polyethylene	SO_x	Sulfur Oxides
NO_x	Nitrogen Oxides	VOC	Volatile Organic Compounds

1.0 Introduction

MassHighway is making initiatives to increase their use of recycled-content products. One of the recycled products that MassHighway is now allowing for use via specifications is recycled plastic offset blocks, which serve as the attachment piece between guardrails and guardrail posts. Guardrails are intended to absorb the impact of the vehicle and redirect it back onto the roadway.

Offset blocks represent a significant opportunity – over the past four years MassHighway construction contracts have required the use of approximately 37,000 offset blocks per year. Plastic offset blocks are becoming a commonly used product in place of wood and steel in other states. A number of other states have developed specifications that either allow or exclusively require use of these plastic blocks.

The primary focus of this study is a cost comparison of offset blocks as it directly affects MassHighway. A secondary focus of this report is to understand the life cycle environmental impacts of blocks, which are not directly reflected in the cost.

2.0 Scope of the Life Cycle Assessment

Life Cycle Assessment (LCA) is a tool to evaluate the impacts associated with all stages of a product's lifecycle from cradle to grave both downstream and upstream. The complete host of potential impacts may be included in a LCA, such as environmental, product performance, maintenance requirements, life expectancy, economics, safety, etc. The assessment inventories both the raw materials utilized (inputs) and the pollution and wastes released (outputs). LCA are utilized to compare the overall environmental impact of one product to another over their lifespan.

Standard stages in a product life cycle include:
- Raw material extraction and refinement
- Product manufacturing and fabrication
- Transportation & distribution
- Product installation, use, & maintenance
- Product recycling & disposal

The basis of an LCA study is an inventory of all the inputs and outputs of industrial processes that occur during the life cycle of a product. This includes the production phase and the life cycle processes including the distribution, use and final disposal of the product. In each phase the LCA inventories the inputs and outputs and assesses their impacts.

Once the inventory has been completed, a LCA considers the impacts. This phase of the LCA is called the impact assessment: LCAs can be very large-scale studies quantifying the level of inputs and outputs. This LCA is limited in scope to a basic inventory.

3.0 Upstream Assessment – Process Descriptions and Impact Inventories

In the following sub-sections each process is described and an inventory is provided of that process's inputs and outputs. This assessment does not include an impact analysis, nor does it include a cost analysis of the upstream processes. Process descriptions are restricted to the most common industry practices. In many cases, materials are handled and/or processed using several different technologies. However, often only one practice predominates.

In all the upstream processes described, labor and equipment are inputs, however, they are not listed becauset they are constant inputs throughout all upstream processes with little qualitative difference that can be determined.

3.1 Pressure-Treated Wood Offset Blocks

The primary source of information in this sub-section is EPA's "EPA Office of Compliance Sector Notebook Project – Profile of the Lumber and Wood Products Industry" (EPA/310-R-95-006).

The manufacturing of pressure-treated wood offset blocks can be described by four processes: timber logging, lumber manufacturing, lumber pressure-treating, and offset block manufacturing.

Logging

Timber logging represents the raw material extraction phase of the product lifecycle. It entails the cutting and removal of trees from the forest. Typically gasoline-powered chain saws or diesel-powered hydraulic whole-tree harvesting machines are used to cut standing trees. Felled trees are de-limbed and then transported to central collection areas either by motorized cable or tractor. At the central collection area, logs are loaded by machine onto trucks for transport to the sawmill.

Cutting equipment and transportation vehicles generate air emissions. Solid waste in the form of limbs and green waste trimmed from logs, non-harvested plants and trees, are left in the cut area. In addition to the listed outputs, logging operations can cause other negative environmental impacts including: run-off and erosion that impact water quality and deforestation that can damage natural ecosystems and destroy habitat.

Inputs: Trees, diesel fuel, gasoline
Outputs:
Air Emissions: Vehicle & equipment emissions (PM, VOCs, CO_x, NO_x, SO_x)
Water Emissions: Not applicable
Solid Waste: Forest slash, waste wood

Lumber Manufacturing

Whole trees (round wood) delivered to the sawmill from logging operations are stored primarily in wood yards. The trees are sprayed with water to prevent them from drying and cracking prior to milling. The mill initially loads whole trees into a debarking machine and cuts the trees into shorter lengths (cants) for milling. The cants are then milled into rough lumber of various lengths and dimension depending on their intended finished product application. Finished lumber is produced from the rough lumber in the planing mill. Sawmills typically use the bark, wood chips and sawdust from milling and planing operations as on-site boiler fuel or sell it for mulch production.

Mills then typically dry the lumber using either an air-drying or kiln-drying process. Kiln-drying is the most common technique used to condition softwood destined for wood preserving with waterborne preservatives. Kiln drying uses heat and forced air to rapidly dry the lumber to a desired moisture content. Large milling operations use kiln drying because of its space and time-savings.

Sawmills commonly treat hardwood lumber with a surface protection to reduce sap staining during storage. However, softwood wood (from which pressure-treated lumber is produced) and kiln-dried wood are not normally subjected to surface protection treatment.

Inputs: Wood logs, diesel fuel, gasoline, water
Outputs:
Air Emissions: Vehicle & equipment emissions (PM, VOCs, CO_x, NO_x, SO_x)
Water Emissions: Contact water
Solid Waste: Bark, wood chips, sawdust

There is very little solid waste generated by the milling process since all residuals are typically used for other products. The wood boilers used for kiln drying are typically fired with wood waste and/or liquid fuel (oil) which generate air emissions. Wood yards generate surface and sub-surface run-off of contact water used to keep logs moist. Most of the solid waste generated in the mill process is beneficially re-used either as boiler fuel or converted into mulch products.

Wood Preserving

The two wood preserving methods are non-pressure and pressure treatment. Non-pressure application methods include dipping, soaking, brushing, and spraying. Pressure treatment involves placing lumber into an enclosed chamber which is pressurized and into which a liquid preservative is then introduced. The pressure forces the preservative into the wood. The most common water-based preservatives are chromated copper arsenate (CCA) and ammoniacal copper zinc arsenate (ACZA). The most common oil-based preservatives are pentachlorophenol (PCP) and creosote. MassHighway specifications require that wood offset blocks be treated with water-based preservatives.

Inputs: lumber, CCA, AZCA, PCP, creosote, water or carrier oil
Outputs:
Air Emissions: PCP, polycyclic organics, creosote, ammonia, boiler emissions (PM, VOCs, CO_x, NO_x, SO_x)
Water Emissions: Dripped formulation mixed with rain water and facility washdown water, kiln condensate, contact cooling water
Solid Waste: Bottom sediment sludges, process residuals

Vapors and volatilized chemicals can be emitted to the atmosphere during many phases of the treatment process. Drips and spills can occur during chemical delivery, mixing, and treatment. Rainwater and spills collected from around the treatment vessel and drip pad contribute to water emissions. In addition, treatment liquid exudes from pressure-treated wood as it returns to atmospheric pressure. It can continue to exude for a period of months.

Offset Block Manufacturing

Wood offset blocks are manufactured at regional sawmills and lumber product manufacturers. Individual blocks are cut from longer lengths of pressure-treated dimensional lumber. MassHighway utilizes the following lengths of block: 14 inches and 21¾ inches. To meet MassHighway design specifications the blocks must be routed. The routed channel allows the block to fit on a guardrail post and prevent the block from rotating. The block must also be pre-drilled for the bolts used to mount them.

Inputs: pressure-treated lumber, diesel fuel, gasoline, water
Outputs:
Air Emissions: Vehicle & equipment emissions (PM, VOCs, CO_x, NO_x, SO_x)
Water Emissions: Contact water
Solid Waste: pressure-treated sawdust and wood chips

3.2 Steel Offset Blocks

The primary source of information in this sub-section is EPA's "EPA Office of Compliance Sector Notebook Project- Profile of the Iron and Steel Industry" (EPA/310-R-95-005).

According to information provided by a steel block manufacturer, the raw steel for this product is manufactured in electric arc furnaces (EAFs) which rely almost exclusively on scrap steel and electricity. Basic oxygen furnaces are used to produce specialty steels, which are not utilized for offset blocks. Thus, only the process for making steel by EAFs will be considered for this analysis. Raw material extraction processes (mining and refining) are not considered due to the almost exclusive use of recycled steel.

It is also important to note that currently steel offset blocks do not meet FHWA crash test criteria and thus may not be used on any new MassHighway projects. However, it is believed that a redesigned steel offset block may soon meet the crash test criteria and thus is considered in this analysis for future potential purchase.

Scrap Metal Recovery

Scrap metal recovery is essentially the raw materials extraction and refining stage prior to steelmaking. Scrap metals are generated in the industrial, commercial, and to a very minor degree, the residential sector. These are manufacturing process wastes, construction and demolition materials from the building industry, transportation related materials (guardrails, railroad materials), scrapped cars and white goods, to name a few.

A very small amount of material, bimetal cans, are generated directly from residents. This material is collected by waste haulers, processed at a material recovery facility, and delivered to scrap dealers. Other scrap metals are segregated from non-metallic materials at the site of generation. Sometimes non-ferrous parts or those containing toxic materials (i.e., PCB capacitors) must be removed from ferrous materials goods using hydraulic shears. In larger operations magnetic separators are utilized. After contaminant removal and segregation, the scrap is graded by quality and baled, compacted or placed into rolloff containers for delivery to the end market.

Inputs: scrap ferrous metal goods, electricity, vehicle and equipment fuel
Outputs:
Air Emissions: Vehicle and processing equipment emissions (PM, VOCs, CO_x, NO_x, SO_x)
Water Emissions: Not applicable
Solid Waste: Non-ferrous contamination (dirt, fines, miscellaneous municipal solid waste), toxic waste (PCBs, refrigerants)

Steel Making

The primary feedstock in the steel making process is scrap steel, which is fed into the EAF to be melted and refined. A variety of grades of scrap steel are used depending on the specifications of the final product. Coke making and iron making, associated with traditional blast furnace operations, are not a part of steel making with electric arc furnaces.

Metal dusts, slag, and gaseous products are produced during this process (see Outputs below.) As the scrap melts, phosphorus, silicon, manganese, carbon and other materials oxidize and form a slag, which must be removed from the molten metal. Oxygen is used to decarburize the molten steel and to provide thermal energy. Emission control systems remove the airborne particulate matter. This dust may be hazardous due to its lead and cadmium content. Much water is used during the steelmaking process for cooling, however, this water is recycled to a large degree.

Inputs: scrap metal, electricity, graphite electrodes, fluxes and alloys (which may include: fluorspar, lime, dolomite), alloying agents (such as aluminum, manganese, and others), water
Outputs:
Air Emissions: CO_x, NO_x, Ozone
Water Emissions: Not applicable
Solid Waste: Emission control dust and sludge (these dusts are primarily composed of iron or iron oxides, flux [lime and/or fluorspar], zinc, and other metals associated with the scrap), slag

Forming

Molten steel is funneled into molds and formed into slabs (blooms) that are rolled into finished products. This process is called continuous casting, and bypasses the ingot-making step used in some steelmaking processes. Hot rolling operations require reheating (up to 2200 degrees F.) The steel moves between two rolling units and the shape is reduced to the desired size. Water is used to cool the formed steel shapes and must be disposed of along with other residual matter that is created during the forming stage.

Inputs: Molten steel, electric energy
Outputs:
Air Emissions: Furnace emissions (PM, VOCs, CO_x, NO_x, SO_x), Ozone
Water Emissions: Process contact water
Solid Waste: Wastewater treatment plant sludge which may contain cadmium, chromium, and lead, mill scale (metallic oxides) generated in the casting process, oil and grease

Steel Offset Block Manufacturing

Steel offset blocks are manufactured from structural steel I beams made of low carbon galvanized steel. The I-beams are cut to length with electrically operated mechanical or hydraulic presses. Holes are punched into the offset blocks so they can be bolted to the posts and guardrails. Then they must be cleaned with a hydrochloric or sulfuric acid solution in order for the galvanizing finish to adhere properly. A byproduct of this process is crystals which are sold to the agrochemical industry as fertilizer components. At this point the blocks are dipped into a hot dip (850 degree), molten zinc, galvanizing solution. Steel particles attach to the zinc, settle out of this process (called dross) and are perhaps sold back to the zinc provider for recovery. The blocks are then dipped into a quench tank (water with dichromate) to cool and prevent oxidation from occurring.

Inputs: steel I beams, electricity, hydrochloric or sulfuric acid, zinc, dichromate and water
Outputs:
Air Emissions: Not applicable
Water Emissions: Wastewater from rinse baths (which may contain zinc, lead, cadmium, or chromium), spent pickle liquor (hydrochloric or sulfuric acid)
Solid Waste: Zinc dross, dichromate

3.3 Recycled Plastic Offset Blocks

For this analysis recycled plastic offset blocks produced by Mondo Polymer Technologies of Reno, OH are used as the standard. These blocks have been the most widely utilized to date. These offset blocks are composed of approximately 95% recycled plastics and 5% carbon black. Virgin plastic resins are very rarely utilized and thus the resin manufacturing stage of virgin plastic production will not be considered here. Carbon black is a by-product of oil and/or rubber manufacturing and is added for UV protection.

Recycled Resin Collection, Processing, and Delivery

Mondo Polymer utilizes post consumer, post industrial and, infrequently, off-spec resins to manufacture its plastic blocks. Plastic product manufacturers generate scrap from their molding and manufacturing processes. Consumers generate scrap plastic from products and packaging at home or in the workplace. The plastic recycling industry includes collectors, processors and handlers who prepare scrap plastic for re-use. In general, post-consumer plastic is collected by trucks at the point of generation, and delivered to a material processing facility. At this facility the plastic may be separated by material type, examined for contaminant removal, consolidated into larger loads, and then baled or put into gaylord boxes. Plastic recyclers and converters typically handle post-industrial scrap. In the case of Mondo Polymer, a significant portion of their post-industrial scrap is delivered directly from the generator to their manufacturing site.

Inputs: Post-industrial, post-consumer, and off-spec plastics, vehicle fuel, electricity
Outputs:
Air emissions: Vehicle emissions (PM, VOCs, CO_x, NO_x, SO_x)
Water emissions: Not applicable
Solid waste: Contaminants (dirt, miscellaneous solid waste material)

Plastic Block Manufacturing

The plastic materials used to create Mondo recycled plastic offset blocks are: 70% low-density polyethylene (LDPE), 30% high-density polyethylene (HDPE). Up to 5% of the feedstock may be trace plastics (PET, PVC, PS, Nylon.). Post consumer feedstock materials include: plastic bottles, caps, barrels, buckets, toys, and other consumer items. Post industrial materials can include any of those previously mentioned, as well as containers, purgings, plant scrap, shrink wraps and films. These materials are leftover or rejects from manufacturers. Some manufacturers of recycled plastic offset blocks use carpet and other fibers, although Mondo does not.

Mondo does not utilize any recycled resin pellet (feedstocks made by plastic converters and blenders), but instead performs their own blending and batching of various recycled feedstocks. It is not known whether or not other plastic offset bock manufacturers use recycled resin pellets.

The plastic feedstock material is delivered both processed and whole. If it is not processed, Mondo puts the material through their own granulators. Mondo does some of their own grinding (flaking) and some is pre-processed elsewhere. This material does not need to be washed, according to Mondo. The material is mechanically ground into flakes using electrically operated equipment. In addition to the grinding there is another proprietary process applied to the regrind to prepare that material for extrusion. Three percent by weight carbon black is added for UV protection. Other proprietary ingredients are added apparently to improve the molding properties of the feedstock.

The flake is fed into electrically operated extruders which pushes the fluidized plastics through a die forming the offset block with channel and hole. This extrusion process creates a finished offset block which does not need to be cut or otherwise finished.

Input: Post-industrial, post-consumer, and off-spec plastics, carbon black, fuel for vehicles (fork lifts, skid steers), electricity, water, proprietary additives
Output:
Air Emissions: Vehicle emissions (PM, VOCs, CO_x, NO_x, SO_x), emission from the molding process (VOCs)
Water Emissions: Quench water
Solid Waste: Not applicable

4.0 Product Utilization Analysis

The product utilization analysis is the most detailed section of this LCA given the fact that MassHighway's greatest interest lies in comparing the full cost of the various offset blocks. This discussion separates the product utilization into three phases: installation; product life and maintenance; and removal, recycling and disposal. Cost estimates are presented at the end of this section.

4.1 Installation

Guardrail systems are installed by contractors. There are two general types of guardrail systems: W-rail and Thrie-beam. W-rail employs a 14 inch offset block to support a guardrail with a W-shaped cross section. Thrie-beam employs a 21 ¾ inch offset block to support a wider guardrail with a three-humped cross section. Both types of guardrail may be installed as single-faced or double-faced depending on the location.

According to tabulations of weighted average bid prices compiled by MassHighway, during the period of 1996 through 1999, annual installation averaged:

• W-Rail single-faced	148,010 lineal feet
• W-Rail double-faced	1,194 lineal feet
• Thrie-Beam single-faced	34,303 lineal feet
• Thrie-Beam double faced	11,283 lineal feet

Based on discussions with MassHighway design engineers and installation contractors, a brief summary was developed of the guardrail installation process. A typical installation crew may consist of the following:

- 10 – 15 workers
- 1 large flat-bed truck with a post-pounding unit
- 2 flat-bed supply trucks with hydraulic booms
- 2 equipment utility trucks
- Safety equipment (e.g., cones, signs, etc.)
- Night-time installation requires lighting and additional safety equipment

For steel block systems, the crew works in separate teams: one team leads by installing the posts, followed by a separate team that mounts the offset blocks, and a third team that hangs and mounts the guardrail. Steel block systems require more hardware than plastic and wood block systems. Steel blocks are bolted to the post and then the guardrail is bolted to the block. Steel block systems employ a back-up plate, which typically is mounted between the rail and the block on every other post. Wood and plastic block systems do not require this plate.

According to one Connecticut installer experienced with plastic block systems, the installation process can be faster than steel block systems. The lead team installs the posts while a second crew assembles guardrail sections, which are laid on the ground. Then the pounding truck comes back and, using a specially designed rail hanger (designed to hold the rail at the proper height and offset distance), holds the rail while a crew places the plastic offset block and mounts it with the single long screw. The same process may be used also for wood block systems.

Two differences were identified between plastic and wood block systems with regard to the installation process. First, according to a West Virginia report, crews frequently need to ream out the pre-drilled holes in wood blocks in order to allow bolting. The report also noted that plastic blocks, though slightly heavier, are somewhat easier to install than wood blocks. Second, Massachusetts' installers have reported that a percentage of wood offset blocks are broken or cracked when delivered making them unusable.

The differences outlined in the preceding paragraphs impact the time and materials, and thus the cost, for installation.

4.2 Product Life & Maintenance

In general, guardrail systems do not receive regular maintenance or repair. According to MassHighway officials, guardrail maintenance and repair occurs almost exclusively due to impacts (car accidents). When this occurs and repair work is ordered, the standard procedure is to replace the damaged blocks with like materials, e.g., steel replaces steel. Contractors typically perform this work for MassHighway.

Officials also identified two deficiencies in wood blocks that affect their useful life time and maintenance requirements. First, wood blocks dry, shrink, split, and rot due to exposure to the natural elements. This can compromise the blocks' structural integrity. Second, the effects of weathering can make ineffective the routed channel, designed to nest the block and post together. As a consequence, as reported by Connecticut DOT, wooden blocks are known to rotate and thus compromise the structural integrity of the guardrail system.

Based on these observations, it was concluded that it would be appropriate to evaluate the cost impact of differing useful "life spans" for blocks as part of the cost analysis (see below.)

According to highway officials in Connecticut, when a plastic block system needs to be repaired due to an impact, some of the old plastic blocks can be re-used because their structural integrity has not been affected by the impact. Conversely, wood and steel blocks from the entire impact area typically are damaged too much to allow re-use. Consequently, plastic blocks may indeed have a longer useful "life span" than steel and wood blocks.

4.3 Removal, Recycling and Disposal

Guardrails are most commonly removed as part of highway widening, re-curbing, and improvement projects. Job specifications generally require that the contractor is responsible for removal and disposal of discarded guardrail components. Disposal options may involve recycling. Steel components are recycled through scrap metal recyclers, while pressure-treated wood blocks are disposed at solid waste incinerators or landfills.

Although MassHighway has no work experience with plastic blocks, for the purpose of this study it is assumed that the blocks will be recycled. One major manufacturer (Mondo Polymers) has stated that it will buy back their own plastic offset blocks for recycling at $1.00 per block if they are stockpiled in sufficient quantities at MassHighway facilities.

4.4 Cost Estimates

Installation Costs

In order to develop comparable cost estimates for each type of offset block, a generic scenario was established for guardrail installation with the following features:

- Single faced
- Straight run with no end treatments (e.g., bridge connections, flared ends, buried ends, etc.)
- 190.5 meter length (the equivalent of 100 post and block components at a standard spacing)

There are 6 different specific guardrail scenarios. For each material type (steel, wood, and plastic) costs were estimated for a W-rail and Thrie-Beam guardrail system. Cost estimates were then developed for each system. The following bullet points summarize the sources of information and assumptions made:

- Materials – material requirements and prices were determined based on discussions with MassHighway officials, materials suppliers, and installation contractors.
- Equipment – Equipment requirements and time estimates were based on information provided by an installation contractor. Equipment operation and maintenance cost estimates were based on prior knowledge.
- Labor – Personnel requirements and time estimates were based on information provided by installation contractors. Hourly labor costs were set based on a review of pay rates for current MassHighway contracts in the Boston district.

While it is not possible to exactly quantify the impacts on installation cost described in Section 4.2, the cost estimates have been adjusted to approximate these impacts. To estimate cost variations between different guardrail systems, several key assumptions were made based on research done. These assumptions are described here:

- Steel block systems require back-up plates in order to maintain a smooth profile.
- Rail washers are included in all scenarios (although MassHighway specs may be modified in the future to eliminate these washers).
- Differences in the installation process described in Section 4.2 provide the basis for a qualitative ranking of the three different offset block systems with regard to installation time. From longest to shortest installation time the ranking is: steel, wood, and plastic. Wood and plastic can be installed faster than steel because there is much less hardware required. Wood may take slightly longer than plastic because bolt-holes may need to be reamed out and defective blocks may need to be handled.
- Based on a contractor's estimated average installation rate of 1500 to 2000 feet per day, the following assumptions were made to determine hourly labor and equipment O&M costs for installing a straight run of single-faced guardrail:
  - Thrie-beam steel on steel 1500 ft/day
  - Thrie-beam wood on steel = 1650 ft/day
  - Thrie-beam plastic on steel = 1750 ft/day
  - W-rail steel on steel = 1750 ft/day
  - W-rail wood on steel = 1900 ft/day
  - W-rail plastic on steel = 2000 ft/day
- Thrie-beam is slower than W-rail installation because it requires more hardware, and the rails are heavier and more difficult to handle.

Table 4-1 summarizes the estimated installation costs for each scenario. See Appendix for detailed cost estimates.

Table 4-1 – Estimated Installation Cost for Guardrail Systems *

	Estimated Cost for 190.5 meters	*Estimated Cost per Lineal Meter*
W-Rail:		
Steel on Steel	$6,369	$33.43
Wood on Steel	$6,074	$31.88
Plastic on Steel	$6,165	$32.36
Thrie-Beam:		
Steel on Steel	$9,599	$50.39
Wood on Steel	$9,216	$48.38
Plastic on Steel	$9,459	$49.65

* Costs estimates based on simple straight run of single-faced guardrail with no end treatments.

W-Rail installation cost estimates range from $31.88 to $33.43 per lineal meter. Thrie-Beam installation cost estimates range from $48.38 to $50.39 per lineal meter.

Net Life Cycle Costs

Installation costs are only part of the total cost picture for MassHighway. Ultimately, guardrail systems are removed and replaced. To more completely consider the full costs of various offset blocks these factors also need to be considered 1) the useful life-span of the different offset blocks and 2) the recycling value or disposal costs of discarded blocks. It was assumed that other removal costs (e.g., labor and equipment requirements) are equal regardless of the type of offset block.

Field tests of plastic and wood offset blocks indicate that plastic blocks will probably have a longer useful lifespan. Wood blocks are reported to be prone to weathering and rot that compromises their structural integrity. On the other hand, preliminary experience suggests that plastic blocks are less prone to degradation and should have a useful life-span equivalent to steel blocks.

The net present cost takes into account these factors so that the various block systems can be compared on an equivalent basis. The net present cost allows comparison (in current year dollars) of products which have different life spans and salvage values/costs. There are three steps to determining the net present cost.

- First, the net current cost is determined (installation cost less recycling value of blocks or installation costs plus disposal cost of blocks).
- Second, future net installation costs are estimated based on a standard annual inflation rate (i.e., an item that costs $100 this year would cost $110 in two years and $163 in ten years based on a 5 % annual inflation rate).

- Third, the future replacement costs are discounted back to current year dollars based on a flat interest rate. The interest rate is used to determine the time-value of money.

Thus the net present cost is the current cost of a future expenditure. Or stated another way, the longer a product's useful life span, the lower its net life cycle cost becomes.

Several assumptions were made in order to complete the new life cycle cost assessment:

- Inflation rate = 3.0%
- Interest rate = 6.5%
- Steel block scrap value = $35 per ton (1.75¢ per pound) assuming that W-rail blocks weigh 10.5 pounds and Thrie-beam blocks weigh 16 pounds
- Plastic block scrap value = $1 per block assuming that W-rail blocks weigh 12 pounds and Thrie-beam blocks weigh 18 pounds
- Wood block disposal cost = $80 per ton (4¢ per pound) assuming that W-rail blocks weigh 18 pounds and Thrie-beam blocks weigh 29 pounds

Table 4-2 presents the net life cycle costs for 10, 20, and 30 year useful product life spans.

Table 4-2 – Net Present Cost for 190.5 meter Guardrail Systems

	Net Current Cost	*Net Present Cost for Replacement after Useful Life of:*		
		10 years	*20 years*	*30 years*
W-Rail:				
Steel on Steel	$6,350	$4,546	$3,255	$2,410
Wood on Steel	$6,146	$4,400	$3,150	$2,332
Plastic on Steel	$6,065	$4,342	$3,109	$2,301
Thrie-Beam:				
Steel on Steel	$9,570	$6,852	$4,906	$3,631
Wood on Steel	$9,332	$6,681	$4,783	$3,541
Plastic on Steel	$9,359	$6,701	$4,797	$3,551

The results of this analysis indicate that plastic offset block guardrail systems have the lowest net life cycle cost for W-Rail regardless of the useful life. Wood block systems have the lowest net costs for Thrie-Rail systems. If wood block systems in fact have a shorter life span than steel and plastic due to material degradation, then their net present costs would be significantly higher for both W-Rail and Thrie-Beam. For example, the net present cost of 20-year wood block W-Rail systems is $3,150 versus a 30-year steel and plastic costs of $2,410 and $2,301, respectively.

5.0 Downstream Assessment

After product utilization, the product must be disposed or recycled. This stage of a product's lifecycle is considered downstream from the product. As in the upstream section of this report, each process is described and an inventory of its inputs and outputs is provided. Here again, process descriptions are limited to the most common industry practices. In many cases, materials are handled and/or processed using several different technologies. However, often only one practice predominates.

5.1 Pressure Treated Wood Offset Blocks

Recycling of wood products often involves turning the material into a mulch product. Pressure treated lumber cannot be utilized for this application due to the chemicals in the wood. Reuse is not a currently viable option due to the small size of offset blocks. Thus disposal is the only option.

The primary hazard associated with pressure-treated wood is the preservative compound. The most common water-based preservatives are chromated copper arsenate (CCA) and ammoniacal copper zinc arsenate (ACZA). The most common oil-based preservatives are pentachlorophenol (PCP) and creosote. During their useful life, wood offset blocks slowly release part of the preservative compound into the environment, which can potentially impact both water and soil quality.

Old pressure-treated timbers are permitted in licensed solid waste disposal facilities (e.g., incinerators and C&D or municipal landfills) provided that a sample of the material has passed a TCLP test. Wood that does not pass the TCLP test must be disposed as hazardous waste. Delivery to a disposal facility entails collection in trucks, perhaps consolidation at a transfer station/staging area, and disposition at the landfill. Both landfills and incinerators are commonly used in the Northeast for solid waste disposal.

Landfills themselves have several potential environmental outputs. Landfills require resource use (land.) As the materials in the landfill decompose, methane gases and carbon dioxides are generated, contributing to greenhouse gas formation. Liquids percolate through the decomposing matter and in lined landfills they are collected via leachate collection systems. Management of landfills is a resource intensive operation which involves heavy use of landmoving equipment and application of daily cover to prevent vector distribution.

Solid waste incinerators generate a variety of outputs derived from the wastes burned as well as the additional fuel sometimes used to assist the burn. Incinerators are equipped with pollution control systems designed to remove some of the pollutants that they release. Nevertheless, they are still significant potential sources of numerous criteria and hazardous air pollutants.

The following inventory covers both landfills and incinerators.

Input: Wood offset blocks, vehicle fuel, incinerator fuel oil, cover material
Outputs:
Air Emissions: Landfill gas (e.g., methane), incinerator & vehicle & equipment emissions (PM, VOCs, CO_x, NO_x, SO_x, and other air pollutants),
Water Emissions: Landfill leachate
Solid Waste: Incinerator ash

5.2 Steel Offset Blocks

The steel offset blocks are fully recyclable. The offset blocks need to be dismantled from the guardrail construction and consolidated by material type. After they are transported to a scrap yard they are consolidated with other steel scrap of the same grade and baled or put into rolloff containers. Non ferrous contamination is removed, i.e., dirt, sand, miscellaneous solid waste. Equipment used for these operations includes magnetic separators, fork lifts, pallet jacks, front or rear end loaders.

After processing, the material is delivered to the final end user, steelmaking operations, of which there are few in the Northeast. The majority of EAFs are located in the South and Midwest. The scrap steel needs no further preparation for use as a feedstock other than to be sorted by grade. This scrap steel is manufactured directly into new steel products, perhaps new offset blocks, as there is no degradation of the material.

Input: Steel offset blocks, vehicle fuel, electricity
Output:
Air Emissions: Vehicle and equipment emissions (PM, VOCs, CO_x, NO_x, SO_x)
Water Emissions: Contact water
Solid Waste: Non-ferrous contaminants

5.3 Plastic Offset Blocks

Mondo will take back their damaged or used offset blocks for recycling. According to Mondo, they require two pallets worth of blocks (300 blocks) to warrant collection. As Mondo delivers their own products to the customer they can utilize their empty trucks to backhaul used offset blocks to their facility in Reno, Ohio for recycling. Thus no gas usage or emission production can be attributed to delivery of used blocks for recycling as the trucks would be travelling that route in any case. It is uncertain whether the Mondo blocks can be reused for other uses or recycled by other reclaimers.

The recycling process is described in the upstream section of this report. Essentially, the blocks are ground in granulators, mixed with carbon black and another proprietary ingredient and extruded into new products.

Inputs: Plastic offset blocks, electricity, water, proprietary additives
Outputs:
Air Emissions: Vehicle emissions (PM, VOCs, CO_x, NO_x, SO_x), gaseous emission from the molding process (VOCs)
Water Emissions: Quench water
Solid Waste: Not applicable

6.0 Summary and Conclusions

This study assessed the life cycle costs and impacts of various guardrail offset blocks. The study was limited to:

- a qualitative inventory of inputs and outputs for both upstream (e.g., manufacturing) and downstream (e.g., disposal) processes for each type of offset block – steel, pressure-treated wood, and plastic
- a detailed cost estimate (including a net life cycle cost estimate) for installation of various guardrail systems for MassHighway projects

Figures 6-1 through 6-3 summarize the life cycle for each type of offset block and the inventory of upstream and downstream inputs and outputs.

The analysis of plastic blocks was limited to a single manufacturer – Mondo Polymers.

The qualitative inventory of upstream and downstream processes was informational in nature only; it does not provide an impact analysis. Based on discussions with MassHighway officials, the inventory was not intended to be utilized in any decision-making capacity regarding selection of offset blocks.

The cost estimates provide a more quantitative comparison of the three types of offset blocks. According to MassHighway officials, this cost information is more crucial to its consideration of the different types of offset blocks.

Guardrail systems that utilize plastic offset blocks appear to be less expensive than those constructed with steel blocks and more expensive that those constructed with wood blocks. The estimated costs for W-Rail systems range from $31.88 to $33.43 per lineal meter – a five percent variation. The estimated costs for Thrie-beam systems range from $48.38 to $50.39 per lineal meter – a four percent variation.

The net life cycle cost estimate considered the salvage value (for steel and plastic) and the disposal cost (for wood) as well as the net present cost for guardrail systems using each type of offset block. The results of this analysis are that while guardrails constructed with wood offset block have the lowest estimated installation cost, guardrails constructed with plastic offset blocks have the lowest estimated net present cost for W-Rail systems. However, for Thrie-beam systems, guardrails constructed with wood offset blocks have the lowest estimated net present cost.

State transportation officials contacted during this project raised concerns about the useful life expectancy of wood blocks. Specifically, there are concerns that wood blocks have a shorter useful life than plastic or steel because the wood blocks can dry out, crack and loose their structural integrity. If this concern is proven to be true, then the net life cycle cost of wood offset block guardrail systems would be much higher than both steel and plastic block systems. For example, the net present cost of 20-year wood block W-Rail systems is $3,150 versus a 30-year steel and plastic costs of $2,410 and $2,301, respectively.

Figure 6-1 Life Cycle Diagram for Pressure-Treated Wood Offset Blocks

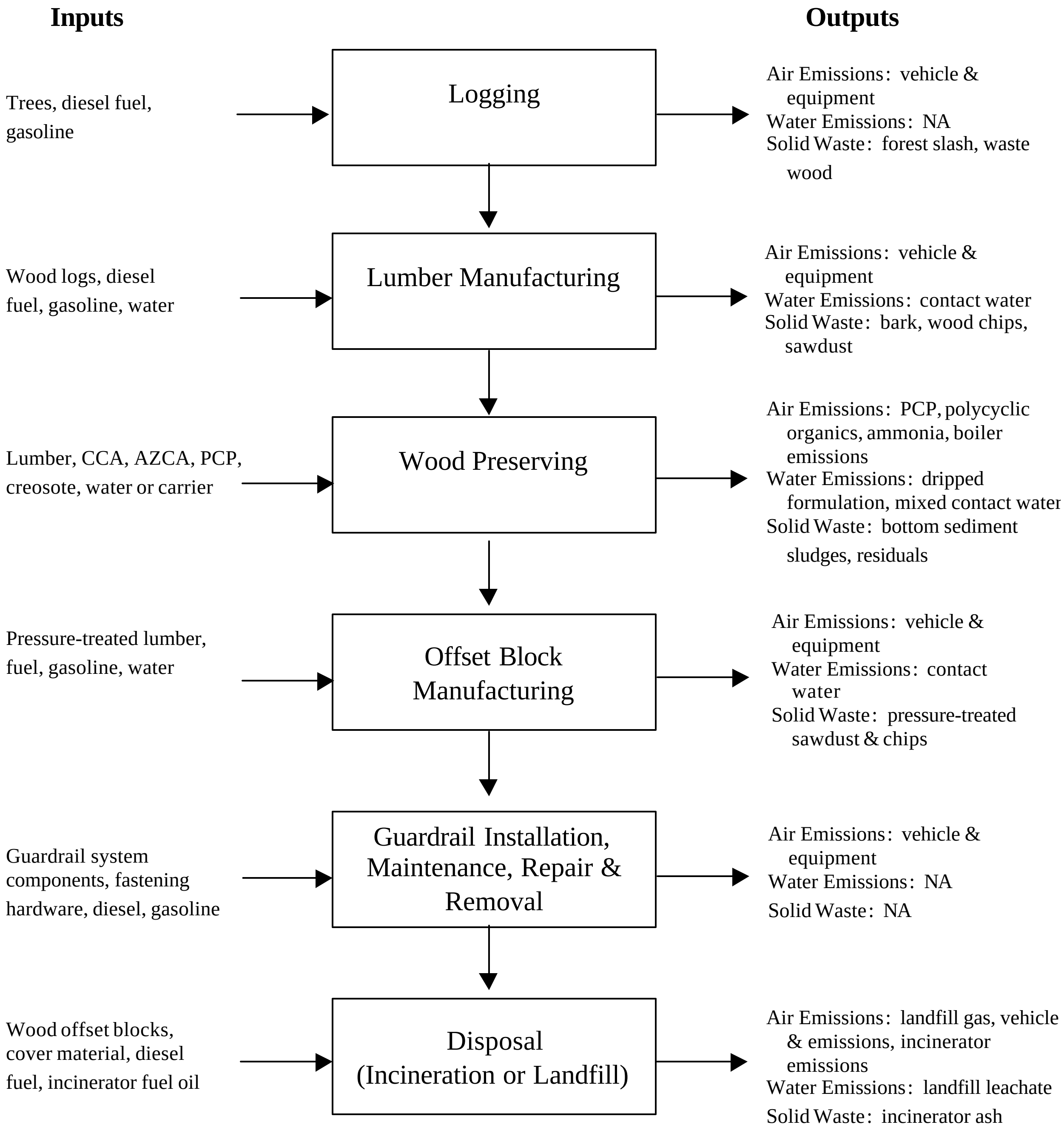


Figure 6-2 Life Cycle Diagram for Steel Offset Blocks

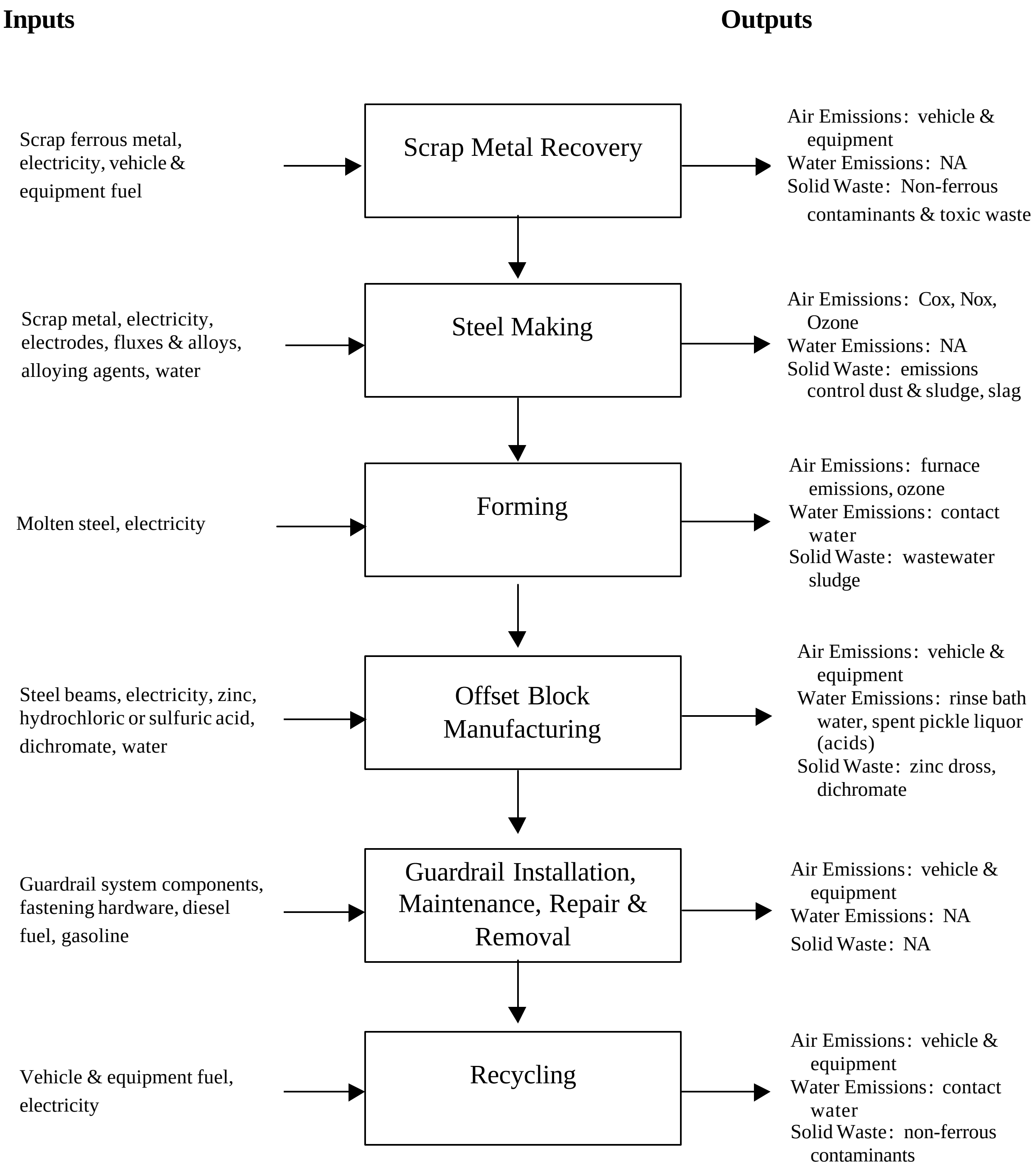
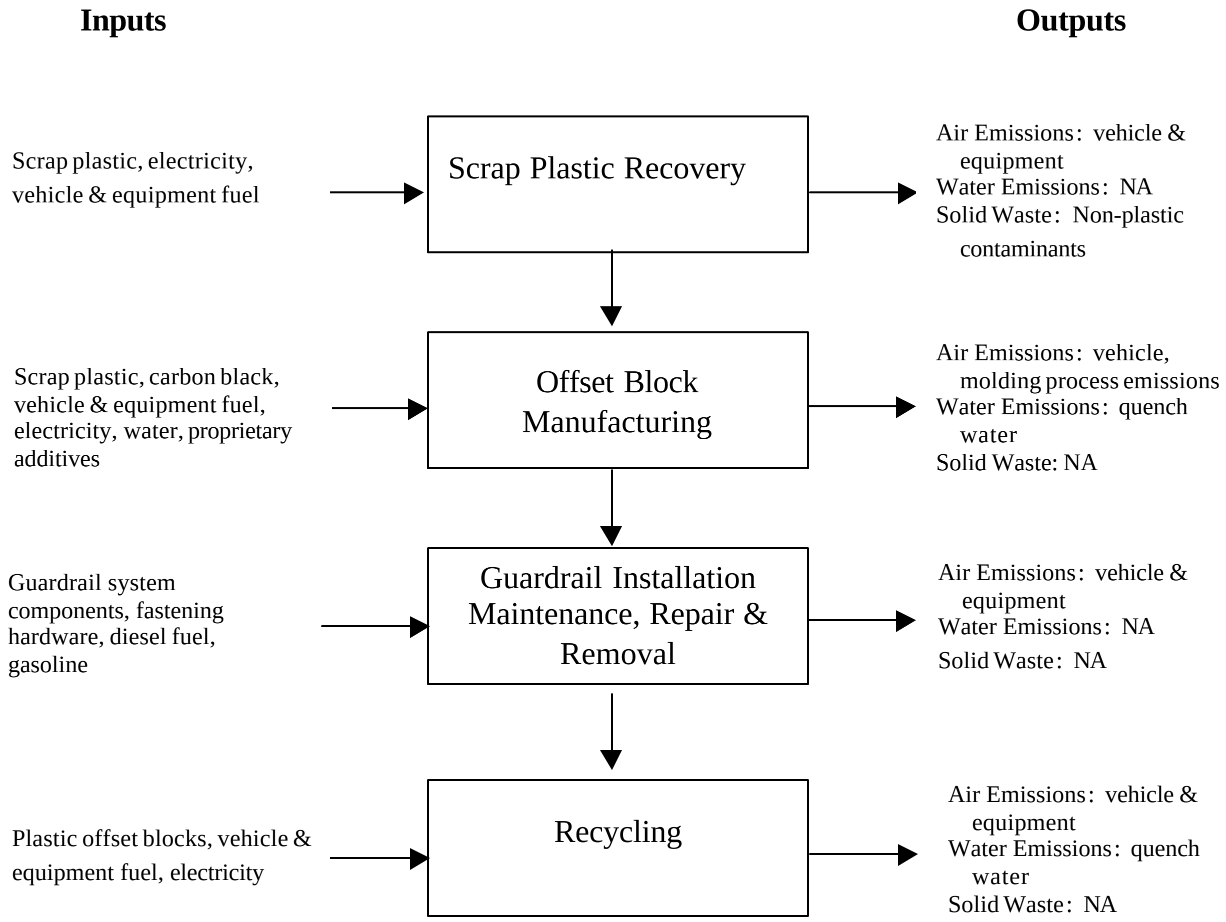


Figure 6-3 Life Cycle Diagram for Plastic Offset Blocks



7.0 Appendix

Installation Cost Estimates for Generic Guardrail Systems
W-Rail

			Steel Post, Steel Block		**Steel Post, Wood Block**		**Steel Post, Plastic Block**	
Material Cost			625 lineal ft @ $6.20/ft	$3,875.00	625 lineal ft @ $6.00/ft	$3,750.00	625 lineal ft @ $6.25/ft	$3,906.25
	Cost/ Hour	Quantity	Hours/Unit or Person	Total Cost	Hours/Unit or Person	Total Cost	Hours/Unit or Person	Total Cost
Equipment								
Post-pounder truck	$35.00	1	2.9	$100.00	2.6	$92.11	2.5	$87.50
Crane truck	$35.00	2	2.9	$200.00	2.6	$184.21	2.5	$175.00
Utility truck	$25.00	2	2.9	$142.86	2.6	$131.58	2.5	$125.00
Flat bed truck	$25.00	1	2.9	$71.43	2.6	$65.79	2.5	$62.50
Subtotal – Equipment				$514.29		$473.68		$450.00
Labor								
Foreman	$32.00	1	2.9	$91.43	2.6	$84.21	2.5	$80.00
Equipment operator	$30.00	3	2.9	$257.14	2.6	$236.84	2.5	$225.00
Laborer	$28.00	10	2.9	$800.00	2.6	$736.84	2.5	$700.00
Subtotal - Labor				$1,148.57		$1,057.89		$1,005.00
Contractor Profit	15%			$830.68		$792.24		$804.19
Total Cost				$6,368.54		$6,073.82		$6,165.44
Cost per Lineal Foot	625 ft			$10.19		$9.72		$9.86
Cost per Lineal Meter	190.5 m			$33.43		$31.88		$32.36

Appendix (continued)

Installation Cost Estimates for Generic Guardrail Systems
Thrie-Beam

			Steel Post, Steel Block		**Steel Post, Wood Block**		**Steel Post, Plastic Block**	
Material Cost			625 lineal ft @ $10.40/ft	$6,500.00	625 lineal ft @ $10.00/ft	$6,250.00	625 lineal ft @ $10.50/ft	$6,562.50
	Cost/ Hour	Quantity	Hours/Unit or Person	Total Cost	Hours/Unit or Person	Total Cost	Hours/Unit or Person	Total Cost
Equipment								
Post-pounder truck	$35.00	1	3.3	$116.67	3.0	$106.06	2.9	$100.00
Crane truck	$35.00	2	3.3	$233.33	3.0	$212.12	2.9	$200.00
Utility truck	$25.00	2	3.3	$166.67	3.0	$151.52	2.9	$142.86
Flat bed truck	$25.00	1	3.3	$83.33	3.0	$75.76	2.9	$71.43
Subtotal - Equipment				$600.00		$545.45		$514.29
Labor								
Foreman	$32.00	1	3.3	$106.67	3.0	$96.97	2.9	$91.43
Equipment operator	$30.00	3	3.3	$300.00	3.0	$272.73	2.9	$257.14
Laborer	$28.00	10	3.3	$840.00	3.0	$848.48	2.9	$800.00
Subtotal – Labor				$1,246.67		$1,218.18		$1,148.57
Contractor Profit	15%			$1,252.00		$1.202.05		$1,233.80
Total Cost				$9,598.67		$9,215.68		$9,459.16
Cost per Lineal Foot	625 ft			$15.36		$14.75		$15.13
Cost per Lineal Meter	190.5 m			$50.39		$48.38		$49.65