Loaders

• Loader: A tractor equipped with a front-end bucket (bucket loader, front-end loader)
• Both wheel loaders and track loaders are available
Loaders II

- Most modern wheel loaders are articulated
  - They are hinged between the front and rear axles to provide greater maneuverability

- Loaders most commonly used for
  - Excavating soft to medium-hard material
  - Loading haul units
  - Stockpiling material
  - Backfilling
  - Moving concrete and other construction materials

Wheel vs. Track Loaders

**Wheel loaders**
- Excellent job mobility
- Capable of over-the-road movement between jobs at speeds of 40km/h and higher
- While their ground pressure is relatively low and may be varied by the use of different-size tires and by changing inflation pressures, they do not have all-terrain capability of track loaders

**Track loaders**
- Capable of overcoming steeper grades and side slopes than are wheel loaders
- Their low ground pressure and high tractive effort enable them to operate in low-traficability soils
- Because of their low speed, their production is less than that of a wheel loader over longer haul distances
Estimating Loader Production

Production = volume per cycle x cycles per hour

• Basic cycle time includes time required for:
  – Loading
  – Dumping
  – Making reversals of direction
  – Traveling a minimum distance

• Typical values for basic cycle time

<table>
<thead>
<tr>
<th>Loading Conditions</th>
<th>Articulated Wheel Loader</th>
<th>Track Loader</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose materials</td>
<td>0.35</td>
<td>0.30</td>
</tr>
<tr>
<td>Average material</td>
<td>0.50</td>
<td>0.35</td>
</tr>
<tr>
<td>Hard materials</td>
<td>0.65</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Estimating Loader Production II

• Use manufacturers’ performance curves to estimate travel time whenever possible.

• Studies show that there is little variation in basic cycle time for wheel loaders up to a distance of 25m between loading and dumping distance

• Therefore, travel time should not be added until one-way distance exceeds this distance
Estimating Loader Production III

- Typical ravel time curves for wheel loaders

Estimating Loader Production IV

- Example 4-7

Estimate the hourly production in loose volume (LCM) of a 2.68 m$^3$ wheel loader excavating sand and gravel (average material) from a pit and moving it to a stockpile. The average haul distance is 61 m, the effective grade is 6%, the bucket fill factor is 1.0, and job efficiency is 50 min/h.
Solution:
Production = volume per cycle x cycles per hour
Basic cycle time = 0.5 min (Table 4-6)
Travel time = 0.3 min (Fig 4-14)
Cycle time = 0.8 min

Production
= 2.68 x 1.0 x (60/0.8) x (50/60)
= 168 LCM/h

Example
Estimate the hourly production in loose measure of a 4.6 m$^3$ wheel loader moving loose material from a stockpile into dump trucks. The average one-way haul distance is 107m (350 ft). The effective grade is 6% and the bucket fill factor is 0.9. Job efficiency is estimated at 50 min/hr.
Estimating Loader Production VII

Solution:
Production = volume per cycle x cycles per hour
Basic cycle time = 0.35 min (Table 4-6)
Travel time = 0.6 min (Fig 4-14)
Cycle time = 0.95 min

Production
= 4.6 x 0.9 x (60/0.95) x (50/60)
= 217.9 LCM/h

Scrapers
Scrapers II

Scraper uses

- Scrapers are capable of excavating, loading, hauling, and dumping material over medium to long haul distances
- The scraper excavates by lowering the front edge of its bowl into the soil
- The bowl front edge is equipped with replaceable cutting blades
- Only the elevating scraper and the Auger scraper are capable of achieving high efficiency in loading without the assistance of a pusher tractor or another scraper

Types of Scrapers I

- Push-Loaded: Single Powered Axle
Types of Scrapers II

• Push-Pull: Tandem- Powered Axle

Types of Scrapers III

• Auger Loading Mechanism
Types of Scrapers IV

- Elevating

Estimated production = Volume per cycle \times \text{Cycle per hour} \times E

Cycle time =

- Spot time
- Load time
- Maneuver time
- Dump time
- Haul Time
- Return Time

- Spot time: The time required for a unit to position itself in the cut and begin loading, including any waiting for a pusher
Estimating Scraper Production II

Table 4-7: Typical values of fixed cycle time for scrapers

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Spot Time</th>
<th></th>
<th>Load Time</th>
<th></th>
<th>Maneuver and Dump Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single Pusher</td>
<td>Tandem Pusher</td>
<td>Elevating Scraper</td>
<td>Auger</td>
<td>Push-Pull</td>
</tr>
<tr>
<td>Favorable</td>
<td>0.2</td>
<td>0.1</td>
<td>0.8</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Average</td>
<td>0.3</td>
<td>0.2</td>
<td>1.0</td>
<td>0.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Unfavorable</td>
<td>0.5</td>
<td>0.5</td>
<td>1.5</td>
<td>1.3</td>
<td>1.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Single Engine</th>
<th>Twin Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Favorable</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Average</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Unfavorable</td>
<td>1.0</td>
<td>0.9</td>
</tr>
</tbody>
</table>

*Per pair of scrapers.

Estimating Scraper Production III

- Variable cycle time (travel time) includes:
  - Haul time
  - Return time
- Estimated by:
  - Travel-time curves
  - Average speed method with performance curve
- It is necessary to break a haul route up into sections having similar total resistance values
- The total travel time is found as the sum of the section travel times
Estimating Scraper Production IV

• In determining the payload per scraper cycle, it is necessary to check both the rated weight payload and the heaped volume capacity
• The volume corresponding to the lesser of these two values will govern

Estimating Scraper Production V

• Example:
Estimate the production of a wheel tractor-scraper given the job information below. Use the travel time curves of Fig 4-4 and 4-5.
  – Scraper type: single-engine
  – Operating conditions: average single pusher
  – Material: sandy clay: 1898 kg/BCM; 1571 kg/LCM
  – Rolling resistance: 50 kg/t
Estimating Scraper Production VI

- Scraper capacity:
  - rated payload = 34,020 kg
  - heaped volume = 24 LCM
- Altitude derating factor = 4%
- Job efficiency = 50 min/h
- Haul route:
  - Section 1. Level loading area
  - Section 2. Down a 4% grade, 610 m
  - Section 3. Level dumping area
  - Section 4. Up a 4% grade, 610 m
  - Section 5. Level turnaround, 183 m

Estimating Scraper Production VII

[Graph showing distance vs time for loaded Scraper 631D (33.25 x 35)]

Figure 4-6: Scraper travel time—loaded. (Courtesy of Caterpillar Inc.)
Estimating Scraper Production VIII

Solution
1. Check load
   - Weight of heaped capacity
   - Rated payload
2. Calculate effective grade
   - Haul
   - Return
   - Turnaround
3. Find cycle time
   - Travel time
   - Fixed time
   - Adjust for altitude
4. Find production
   Estimated production = Volume per cycle x Cycle per hour x E
Estimating Scraper Production X

1. Check load
   - Weight of heaped capacity
   - Rated payload

Weight of heaped capacity = 24 LCM x 1571 kg/LCM
   = 37,794 kg > rated payload = 34,020 kg

Therefore, maximum capacity
   = 34,020 kg / (1571 kg/LCM) = 21.7 LCM

OR, in bank measure
   = 34,020 kg / (1898 kg/BCM) = 17.9 BCM/load

Estimating Scraper Production

2. Calculate effective grade
   - Haul
   - Return
   - Turnaround

Haul = -4% + 50/10 = 1%
Return = 4% + 50/10 = 9%
Turnaround = 0 + 50/10 = 5%
Estimating Scraper Production

3. Find cycle time
   • Travel time
   • Fixed time
   • Adjust for altitude
   • Travel time
     – Section 2 (haul, 610m, 1% grade): 1 min (Fig 4-4)
     – Section 4 (return, 610m, 9% grade): 1.6 min (Fig 4-5)
     – Section 5 (turnaround, 183m, 5% grade): 0.45 min (Fig 4-5)

Travel time = 1.04 [1 + 1.6 + 0.45] = 3.2 min

Altitude adjustment

Estimating Scraper Production

3. Find cycle time
   • Travel time
   • Fixed time
   • Adjust travel time for altitude
   • Fixed time
     – Spot time = 0.3 min Table (4-7)
     – Load time = 0.6 min Table (4-7)
     – Maneuver and dump time = 0.7 min Table (4-7)

Fixed time = 0.3 + 0.6 + 0.7 = 1.6 min

Total cycle time = 3.2 + 1.6 = 4.8 min
Estimating Scraper Production

4. Find production
Estimated production
= Volume per cycle x Cycle per hour x E

= 17.9 BCM x (50/4.8)

= 186.5 BCM/h
Push Loading

• Some scrapers require the assistance of pusher tractors to obtain maximum production
• 3 basic loading methods
  – Back-track
  – Chain
  – Shuttle

Push Loading II
Push Loading III

• Back-track loading
  – Most commonly used since it permits all scrapers to load in the same general area
  – Offers the advantage of always being able to load in the direction of the haul
  – The slowest of the three methods because of the additional pusher travel time

Push Loading IV

• Chain loading
  – Suitable when the excavation is conducted in a long cut
Push Loading V

- Shuttle loading
  - Requires two separate fill areas for efficient operations
  - Infrequent use
  - Pusher can serve scrapers hauling in opposite directions

Push Loading VI

Pusher cycle time

- Pusher cycle time consists of:
  - Maneuver time: while the pusher moves into position and engages the scraper
  - Load time
  - Boost time: the pusher assists in accelerating the scraper out of the cut
  - Return time
Push Loading VII

- Calculating the number of pushers required
  - The number of scrapers that can be handled by one pusher without a scraper having to wait for a pusher
- Number of scrapers served = scraper cycle time / pusher cycle time
- Number of pushers required = number of scrapers / number served by one pusher

Push Loading VIII

- When the number of pushers actually used is less than the required number to fully serve the scraper fleet, expected production is reduced
  - Production =
    (No. of pushers / required No.)
    x No. of scrapers x Production per scraper

<table>
<thead>
<tr>
<th>Loading Method</th>
<th>Single Pusher</th>
<th>Tandem Pusher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back-track</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Chain or shuttle</td>
<td>1.0</td>
<td>0.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3.5</strong></td>
<td><strong>5.3</strong></td>
</tr>
</tbody>
</table>
**Push Loading IX**

- **Example**

  The estimated cycle time for a wheel scraper is 6.5 min. Calculate the number of pushers required to serve a fleet of nine scrapers using single pusher. Determine the results for both back track and chain loading methods.

**Push Loading X**

Back track loading:
- Pusher cycle time = 1.5 min
- No. of scrapers served = 6.5/1.5 = 4.3 scrapers
- No. of required pushers = No. of scrapers / No. of scrapers served by one pusher = 9 / 4.3 = 2.1 pushers = 3 pushers

<table>
<thead>
<tr>
<th>Table 4-8 Typical pusher cycle time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading Method</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Back-track</td>
</tr>
<tr>
<td>Chain or shuttle</td>
</tr>
</tbody>
</table>
Push Loading XI

Chain loading:
Pusher cycle time = 1 min
No. of scrapers served = 6.5/1 = 6.5 scrapers
No. of required pushers
= No. of scrapers / No. of scrapers served by one pusher
= 9 / 6.5 = 1.4 pushers = 2 pushers

<table>
<thead>
<tr>
<th>Loading Method</th>
<th>Single Pusher</th>
<th>Tandem Pusher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back-track</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Chain or shuttle</td>
<td>1.0</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Push Loading XII

• Example
Find the expected production of the previous example if only one pusher is available and the chain loading method is used. Expected production of a single scraper assuming adequate pusher support is 173 BCM/h
Push Loading XIII

Production =
(No. of pushers / required No.)
x No. of scrapers x Production per scraper

= \left(\frac{1}{1.4}\right) \times 9 \times 173 \text{ BCM} = 1112 \text{ BCM/h}

Job Management

• Techniques for maximizing scraper production
  – Use downhill loading whenever possible to reduce the required pusher power and load time
  – Use chain or shuttle loading methods if possible
  – Use rippers to loosen hard soils before attempting to load
  – Have pushers give scrapers an adequate boost to accelerate units out of cut
  – Keep the cut in good condition by providing adequate drainage to improve trafficability
Job Management II

- Maintain the haul road in the best possible condition (use a grader)
- Make the haul road wide enough to permit high speed hauling without danger

Trucks and Wagons

- Hauling: The transportation of excavation
- Hauling Equipment: Loader, Dozer, Scraper, Trucks, Wagons, Conveyor Belts, Trains
- Wagons: Earthmoving trailers pulled by tractors or truck-tractors

Truck
Trucks and Wagons II

Hauling Equipment

• Trucks
  – Most commonly used
• Conveyor belts
  – Portable units used for movement of bulk construction materials within a small area or for placing concrete
  – Conveyors are capable of moving earth and stone relatively long distances at high speed

Determining the Number of Haul Units

• Truck or Wagon cycle time
  – Fixed: spot, load, maneuver, and dump
  – Variable: haul and return
• Load time = haul unit capacity / loader production at 100% efficiency

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Bottom Dump</th>
<th>Rear Dump</th>
</tr>
</thead>
<tbody>
<tr>
<td>Favorable</td>
<td>1.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Average</td>
<td>1.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Unfavorable</td>
<td>2.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>
Determining the Number of Haul Units II

- Load time = number of bucket loads x Excavator cycle time
- Number of haulers required (N) = haul unit cycle time / load time
- Expected production = (actual number of units / N) x Excavator production

Determining the Number of Haul Units III

Example

- A) Calculate the number of trucks theoretically required and the production of this combination
- B) Calculate the expected production if two trucks are removed from the fleet
  - Shovel production at 100% = 283 BCM/h
  - Job efficiency = 0.75
  - Truck capacity = 15.3 BCM
  - Truck cycle time (excluding loading) = 0.5 h
Determining the Number of Haul Units IV

Solution
A) Loading time = 15.3 / 283 = 0.054 h
Truck cycle time = 0.5 + 0.054 = 0.554 h
Number of trucks = 0.554/0.054 = 10.3 trucks
= Use 11 trucks
Production = 283 BCM/h x 0.75 = 212 BCM/h
B) Production = (9/10.3) x 283 x 0.75 = 186 BCM/h

Job Management

- Special consideration should be given to the size of the haul unit in relation to the excavator
- Empirical studies found that haul units capacity should be 3-5 times excavator bucket capacity
- Clamshells and draglines require even larger sizes (5-10 times excavator bucket capacity)
- A major source of inefficiency is the time lost in spotting haul units for loading
Job Management II

- Techniques for maximizing haul units production
  - Do not overload haul units. Overloading results in excessive repair and maintenance
  - Maintain haul roads in good condition to reduce travel time and minimize equipment wear
  - Develop an efficient traffic pattern for loading, hauling, and dumping
  - Roads must be wide enough to permit safe travel at maximum speeds
  - Provide standby units (20% of fleet size) to replace units that break down