EFFECT OF TRUCK PAYLOAD WEIGHT ON PRODUCTION

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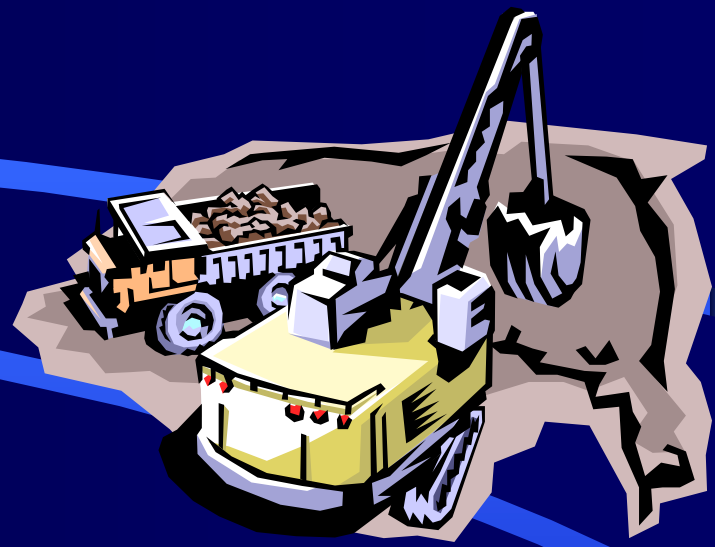

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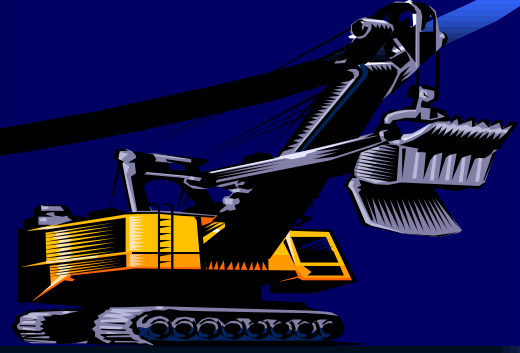
Introduction :



IDEAS :

- **Most constructors intuitively understand that there is a relationship between Payload weight and haul unit performance.**
- **At the same time, PM push limit of rated truck Payload as they seek increased productivity.**
- **It is believed that, increased productivity translate into reduced project cost.**

(Productivity - Project Cost)

Objective :

- **Quantitively examine the relationship between :**

  1. Payload weight and Haul unit performance

  2. Truck Payload Rate Vs Productivity

  3. Increase productivity Vs Project Cost

Method

- **Productivity Improvement translate into Cost reduction, construction managers interested on factors influencing earthwork operations.**

Off highway Haulage Truck :

- Capacity 25 - 300 Tons

- Carrying ⟶ 75 - 170 Tons

- **Speed at Full Load ⟶ 48km/h**
- **Haul road grade : 2-4% (max.10%)**
- **Haulage Trip : 3.2 - 4.8km**
- **Common practice to load haul trucks by volume because operator depends on sight**
- **Emphasis on loading speed not the precise measure of the load amount**

Problem Statement :

The properly loading a haul truck often means putting the exact weight, not necessarily maximum volume of material on the truck.

The question is : What effect does payload weight have on haul unit productivity ?

Productivity Study

- **54300 Truck Cycle**
- **14419 Operating Hours**
- **7 Caterpillar 785 B (CAT785B)**
- **8 Millions Tons of Material**
- **New Truck (Age not a study factor)**
- **The haul route : Down hill :- loaded/uphill empty (from the rock quarry to crusher)**
- **Driver skill was not considered a factor, because the driver has no control over the amount of material loaded on the truck**
- **Data collected using Truck Production Management System TPMS.**

- *Continuation* -

TPMS is an on board data collection platform that Tracks :

1) Pay load Weight
2) Number of Cycles
3) Load Time
4) Travel Time

TPMS uses strut pressure sensor and an on board micro processor to determine payload weight

Seven Trucks used for the study CAT-785 B

Capacity : 130 - 150 Tons
Classes : Off Highway Trucks

Volumemetric hauling capacity : 102LCY

Excavator used : Caterpillar 5320 front shovel 22.2 LCY. Bucket, it can load 785 B in 5 Passes.

Average Grade 8.7%, R.R 1.5 - 2.5%
Normal load time : 2 minutes (Two 10 Hrs. shift, 5 days a week & 8 Hrs. shift on Saturday)

Perspective

- **Limited information describing “the effect of pay load weight on haul unit productivity”.**
- **Caterpillar provide information on productivity based on “rated” load conditions.**
- **Most instructive resources come from mining industry.**
- **Since Haulage represents a major expense in the majority of Earth moving operations, there is ample motivation to increase productivity and thereby reduce operation cost.**

Cost

- **Bottom line measure based on :**

  $/Ton or M^3 of material moved

- **This measure Focuses on :**

  1) Productivity (Units of Materials moved).

  2) Operation expenses.

- **One way to increase Productivity is by loading more into each truck (ie., above haul units rated capacity)**
- **According to Chironis (199) : over loading by 20% might increase haulage rate by 15% allowing for slight increases in time to load and haul .**
- **Chironis claim that the cost per ton hauled should show a corresponding decrease, (Since, direct cost will not change and fuel cost will increase slightly).**

Production Definition

- Data sorted by :
  - a) Five Designated Cycle Distance (Segments)
  - b) Eight Load range Categories

The payload data was analyzed by load ranges to determine payload effect on haul unit productivity

$$\text{Production rate Ton/h} = \frac{\text{Actual Load Weight (T)}}{\text{Total Cycle Time (Min)}} \times 60 \text{ Min/h}$$

Pay Load :

- Pay load is “the load that a vehicle can carry exclusive of vehicle weight”
- Limiting factor is the tires ability to carry the load.
- CAT.Specification Minimum capacity of 785 B truck = 150 Ton
- Operating weight : 94,880kg empty
- Maximum gross weight : 249370kg (GVW) GVW is the critical element in figuring a trucks load carrying capability.

- Continuation -

- To increase the truck's volumetric capacity, following are added :

  1) 0.61 meter side boards(added 1,088kg to operation weight).
  2) Optional body package (weight increase by 2285kg)
  3) Heavy duty body liner (added 7637kg)

- Total operating weight increased to 105,881kg.

- Maximum payload with side boards = Max GVW - Operating weight
  = 249370 - 105881

- These additional weight decreased the maximum payload weight of the trucks from 170 to 158 Ton.
- Maximum pay load : 150 Tons

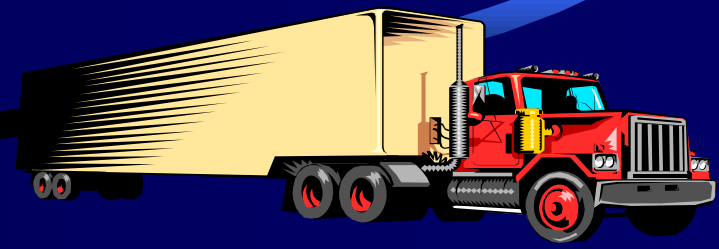
- The sideboards reduced the maximum gravimetric payload of the 785B Trucks approximately one metric ton, while increasing the volumetric capacity by 14 LCY.
- The added weight of optional body and equipment package, plans the sideboards decreased the maximum payload weight of the truck from 170 to 158 Tons .
- Average monthly production without side board : 974161 Tons
- Average monthly production with side board : 897174 Ton

Difference : 76987 Tons (=8%)

Difference is the result of : sideboard, body line and body package

- The exact effect of the sideboard on production is not clear.
- At the same time, the sideboards increased the average payload of the hauling fleet, project requirement caused the encourage one-way haul to increase by 0.8km.
- This increase in haul distance and the resulting longer cycle time reduce average production.
- Truck availability after the sideboards were added was better by 5%, ie., contribute to increase production.

However, the overall effect from sideboards, increased haul and availability was a reduction in monthly production.

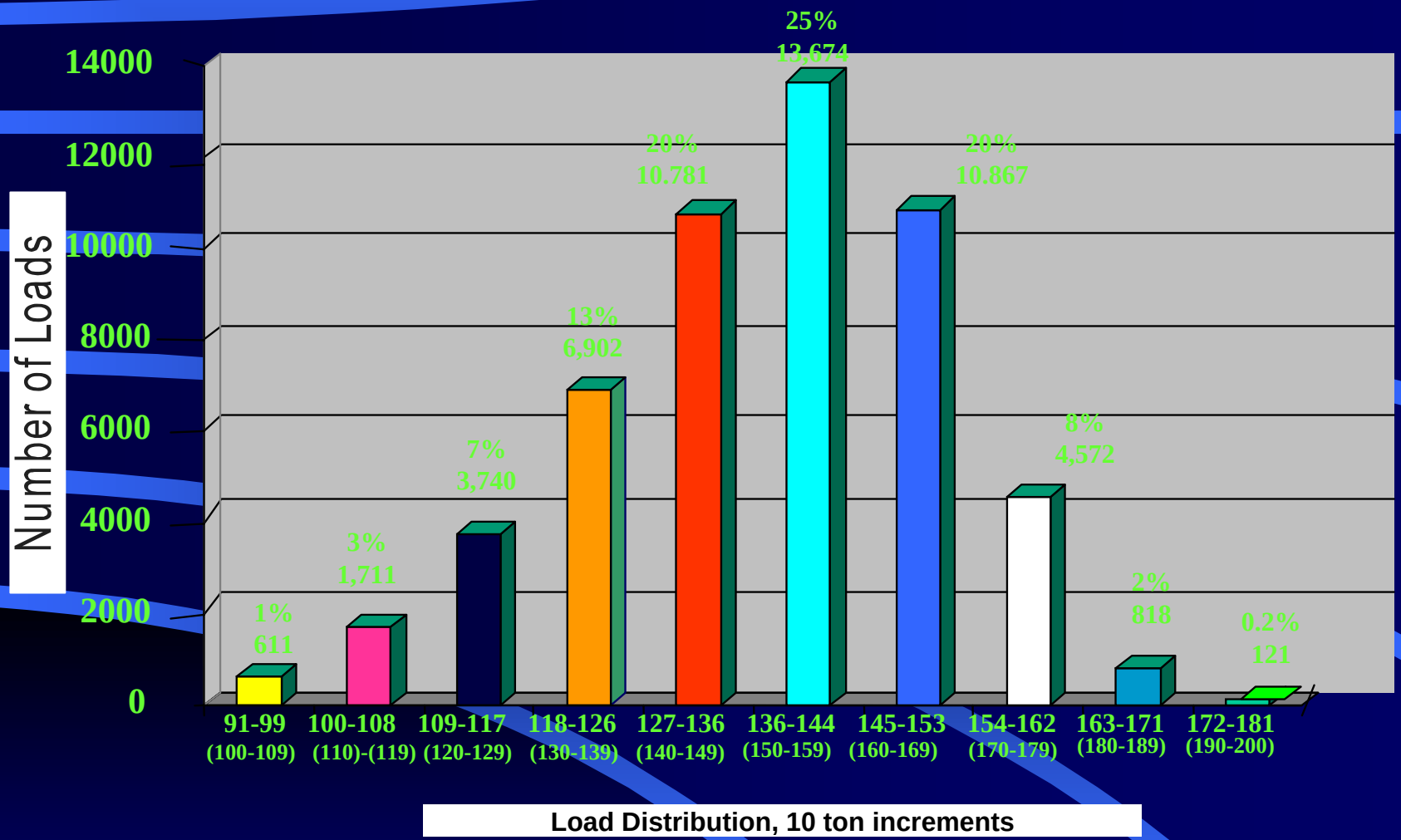


PAYLOAD DATA

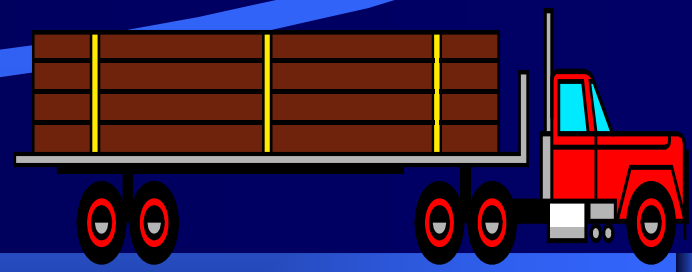
The payload frequency distribution is shown in Fig.2

- **The payload distribution help interpret the 54300 payload cycles by identifying when the payloads fell with respect the class rating and the contractor selected nominal payload for the 785B Trucks.**
- **The payload cycles for the 140 < 160 Ton encompasses 45% of total payload cycle**
  (44% fall within 140 to < 150Ton)
  (The remains 56% makeup the 150 < 160 Ton)
- **56% of the total payloads cycles completed exceeded caterpillars design rate capacity is 150 Tons.**

Fig.2 PAY LOAD FREQUENCY DISTRIBUTION



Average Tons Per Hours Production



- **Production reate depends on**
  - **a) The size of the Haulage Truck**
  - **b) The efficiency of the Haulage Truck**
  - **c) The time to go through complete cycle**

Haul unit cycle time = (Load + Haul + Turning and dump + return + spot time)

- **The cycle time depends on the rate at which the Truck is loaded, moves, dump and return.**
- **Cycle distance is often the determining factor in the production cycle (Chironis 1985, Morgan 1988, Kurshenar 1984)**
- **The common presumption is that as the payload weight increase, production as per hour basis will likewise increase.**

This relationship, however, is not linear; as the average payload of the haul units approaches exceeds their rated capacity there is a noticeable decrease or leveling of the production curve resulting from the over-loaded condition (Fig : 3 - 7)

Fig-3 Average Productivity for Day Shift, Haul Distance 1.6-1.8 km (1-1.1 mi)

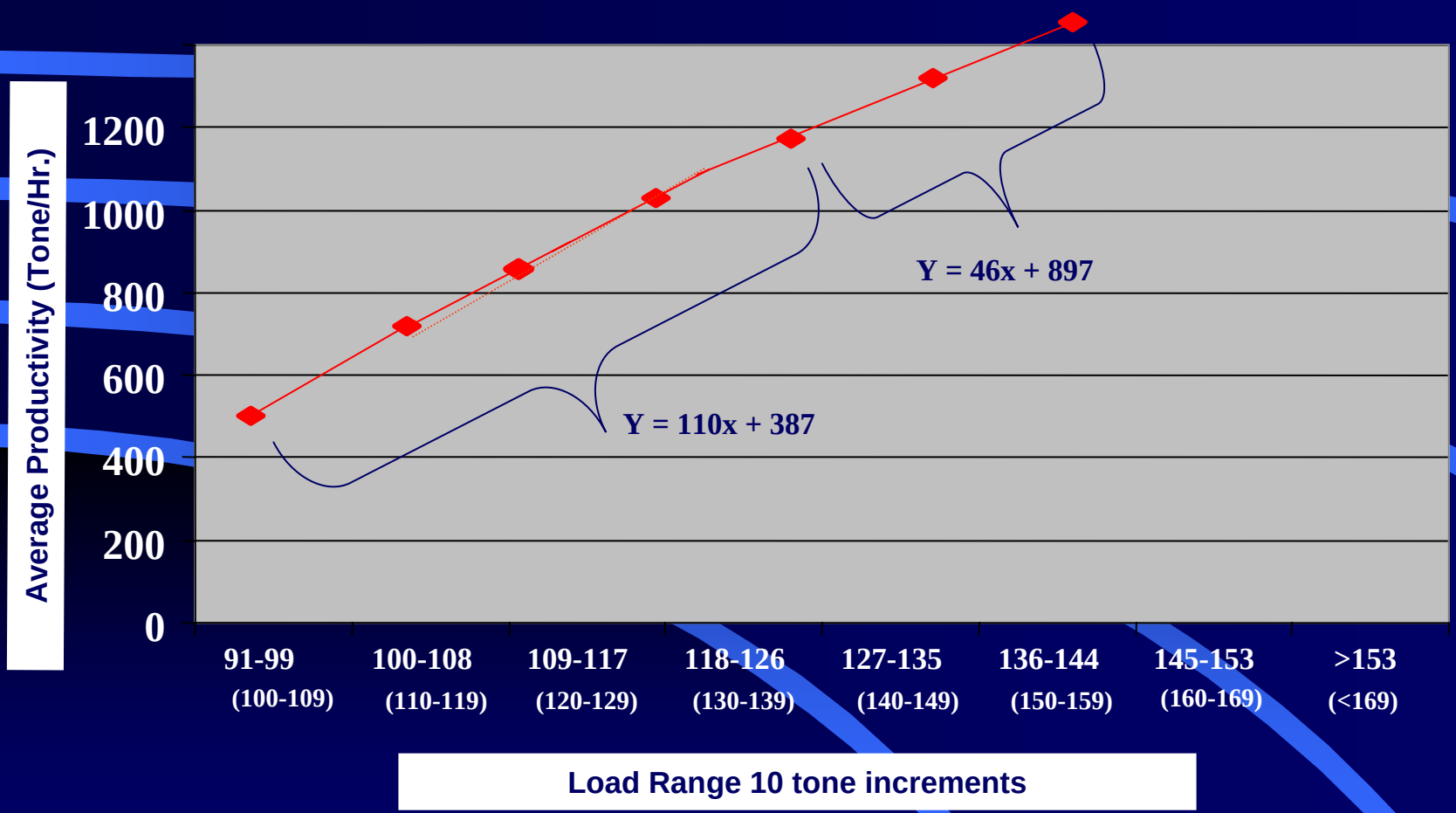


Fig.4 Average Productivity for Day Shift, Haul Distance 1.9-2.1 km (1.2-1.3mi)

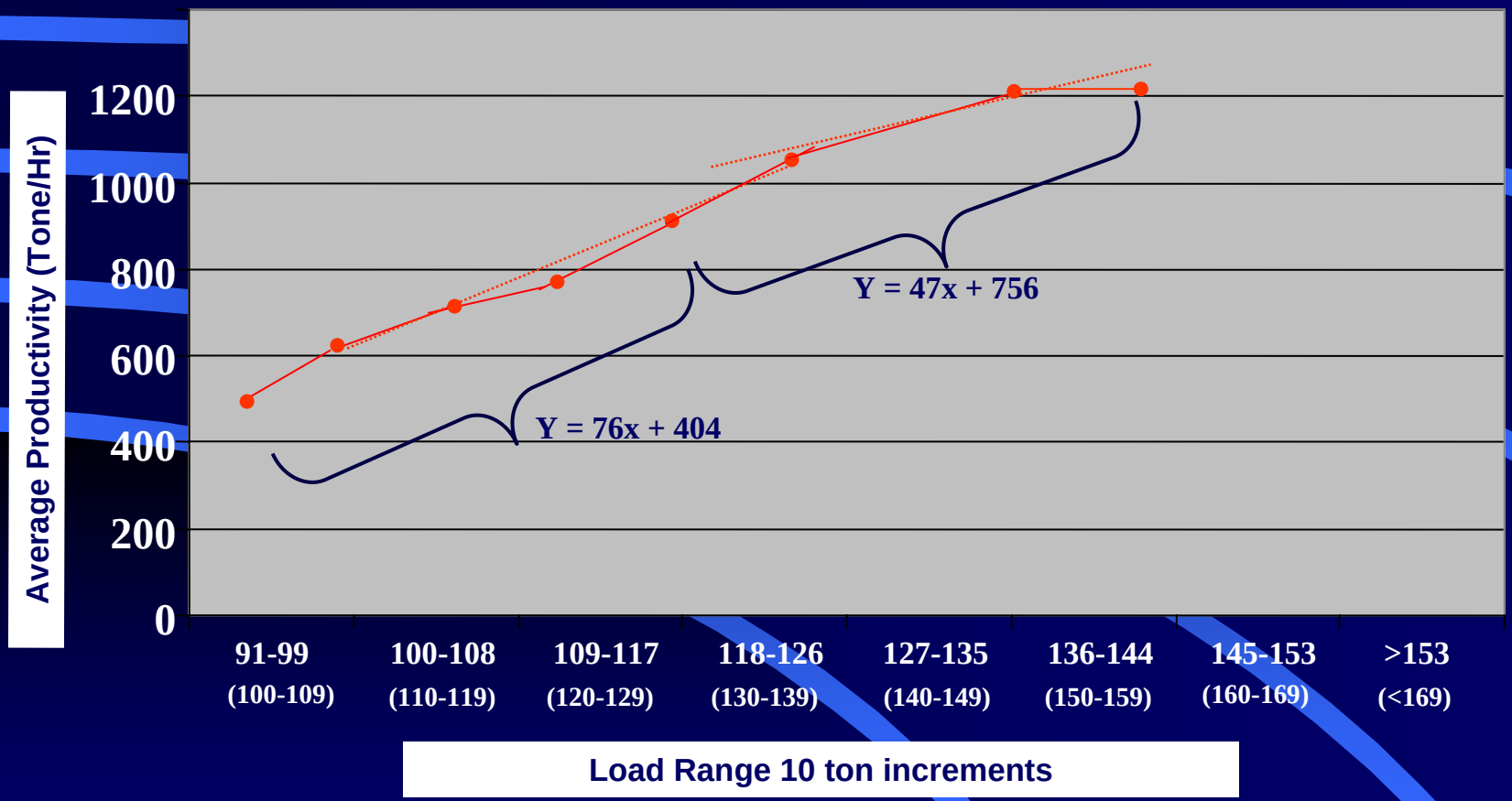


Fig.5 Average Productivity for Day Shift, Haul Distance 2.3-2.4 km (1.4-1.5mi)

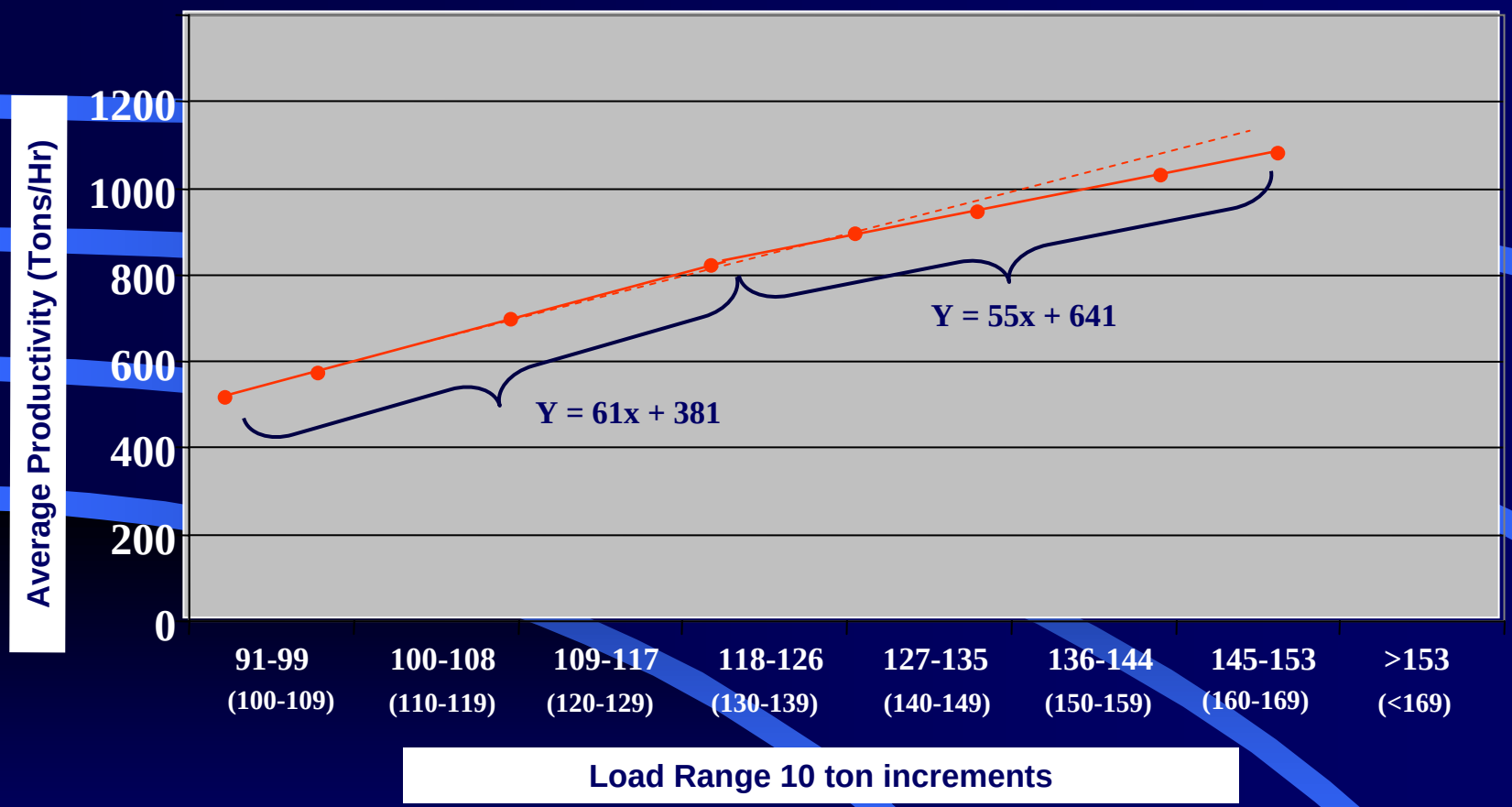


Fig . 7 Average Productivity for Day Shift, Haul Distance 2.9-3.1 km (1.8-1.9mi)

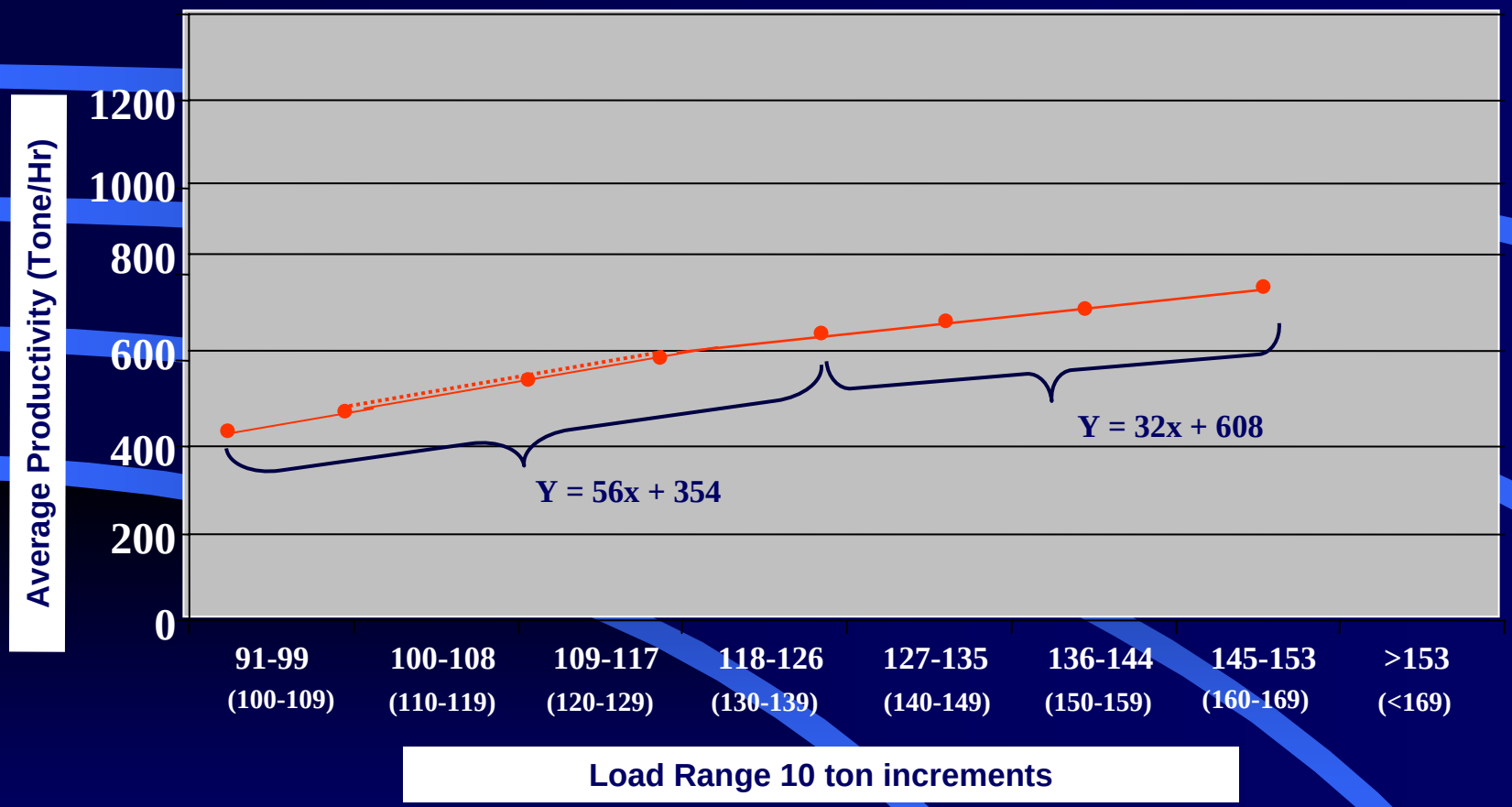


Figure 3 - 7 shows the following :

- **For all cycle distances the average productivity increased as the Payload increases.**
- **As the cycle distance increases, the overall productivity decreases (1184 T at 1.6-1.8km) (735 T at 2.9-3.1km)**
- **Factors that drive this decrease in Production :**
  - **A) The increase in cycle distances contribute to increase in cycle time resulting in few load for a given time period.**
  - **B) The effect haul distance has on loader-truck match ratio.**
- **Match Ratio : Is a function of the Truck and loader cycle time**
- **Variation in the cycle time of either will effect the potential production of the Truck shovel spread**
- **The result of a longer haul distance is under utilization of shovel and decreased production**
- **As the hauling distance changes, there is a need to adjust the number of trucks required to maintain the optimum fleet match (Chironis 1985)**

Effect of Load Exceeding Rated Payload

Graphed production data shows that :

- **The rate of the production increase, caused by increased payload, changes as the payload exceeded 150T.**
- **This reduction could be attributed to : Longer Load times and a decrease in the haul unit's loaded travel speed.**
- **Reduction in the slopes as loads exceeded the "nominal" 150Ton limit, indicates a reduction in the rate of productivity increase.**
- **Although there is an increase in production resulting from the increased payload, the graphs shows that the rate of production increase is much greater when the payload does not exceed the trucks rated capacity .**
- **The slope analysis revealed a 20-65% decrease in the slope of the production line when payloads are increased above the truck's 150Ton rated capacity**
- **The resulting decrease in the incremental production gains is attributed to the increase in the average payload of the hauling fleet.**

Results :

Diminished productivity increase when the load weight exceeded the trucks rated gravimetric capacity.

Adding sideboards, actually caused the average monthly production of the fleet to decrease.

The plot of load Vs times weight appears to indicate a Human factors relationship between load time and providing the shovel operator load weight information with indicator lights mounted by the Truck. (Time Vs Load)

Loading Time Vs Payload Weight

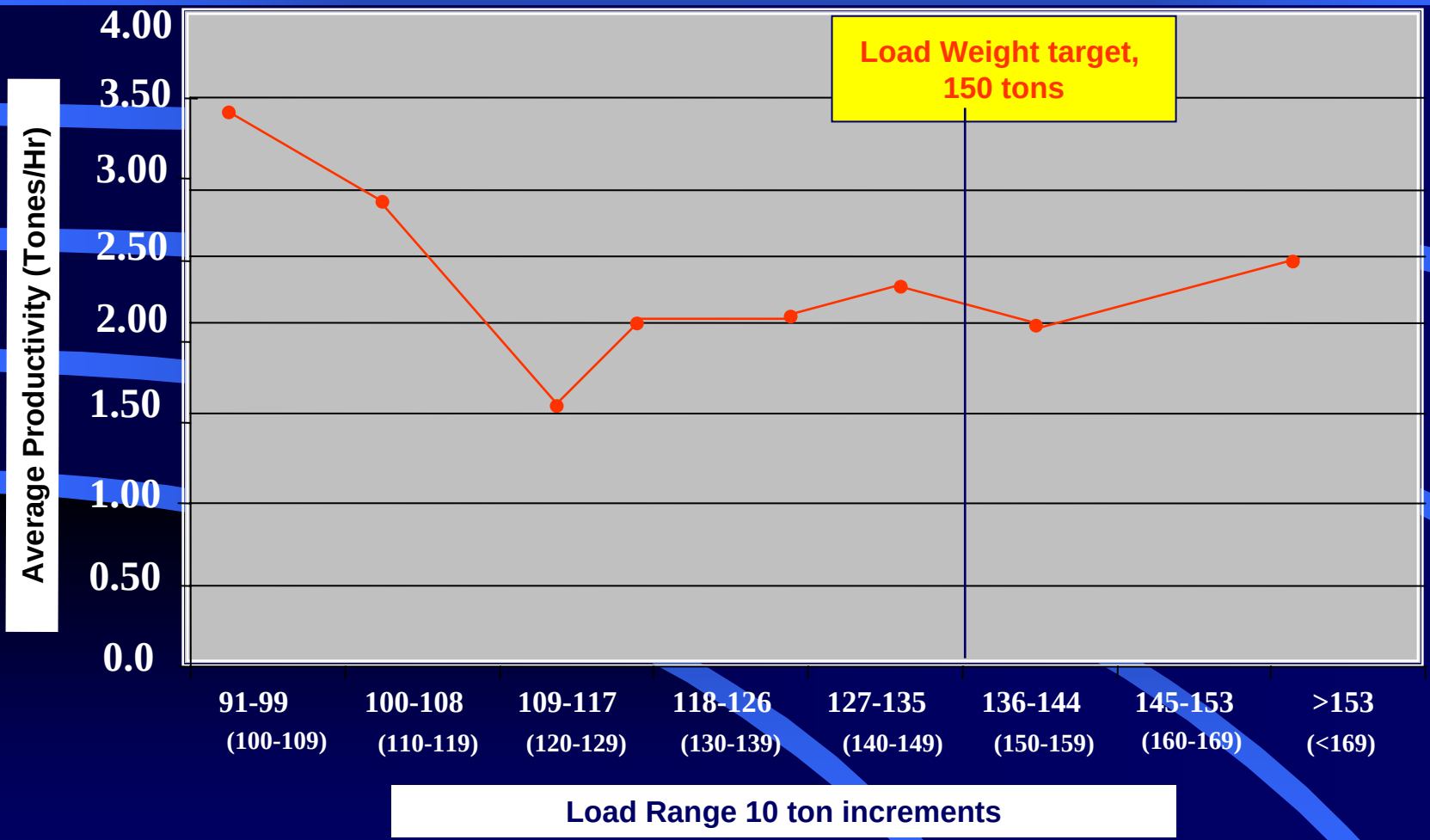
- Load time was examined to determine the relationship between the time duration to load the trucks and the payload weight.
- Hypothesis : “As the average payload increased there would be an increase in the load time duration”.
- The assumption was that the shovel would be adding more bucket loads of material.
- However, data didn’t prove the hypothesis, instead, the results indicated a decrease in the load time as the load range increased. (See Figure 8)
- Consider the heaped capacity of the truck is 102 LCY, and the bucket capacity of the shovel is 22.2LCY, it takes 4.6 bucket loads to fill a truck (102 / 22.2 = 4.6)
- If 4 bucket placed : (4 x 22.2 x 2900) / 2000 = 129 Tons.

if 5 bucket placed : (5 x 22.2 x 2900) / 2000 = 161 Tons.

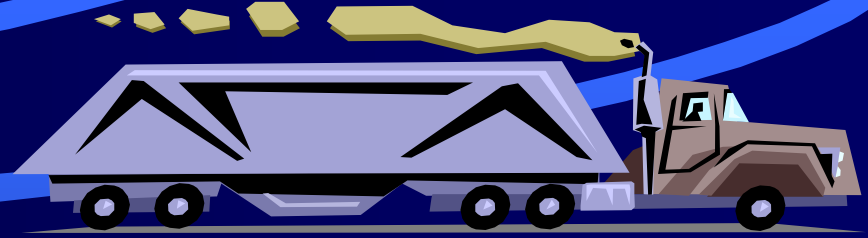
- The assumption from this scenario is that the last bucket cannot be a full bucket.
- The shovel operator works most efficiently when an integral number of bucket “full” loads exactly matches truck capacity (129 & 160T).
- If the load must be kept below 150T the shovel operator must spend time adjusting bucket volume to match the desired (150T load target.
- The human factor’s effect is that when the little red light starts to flash load cycle time suffers because the shovel operator recognize that the truck payload will be exceed if the next bucket load is too large.

Fig . 8

Day Shift Load Time Cycle Analysis



Load Vs Speed



• It was believed that as the payload weight increased the average hauling speed would decrease.

Since, the trucks were hauling downhill, their Automatic Retarder Control (ARC) would limit their haul speed, thus providing consistent haul speeds for all truck payloads.

RESULTS :

•ARC system was limiting the downgrade haul truck speed.

•However, with heavier loads, greater than 159Tons the drivers are using a lower gear, which causes a slight decrease in speed about 3.2km/h.

(See fig. 9)

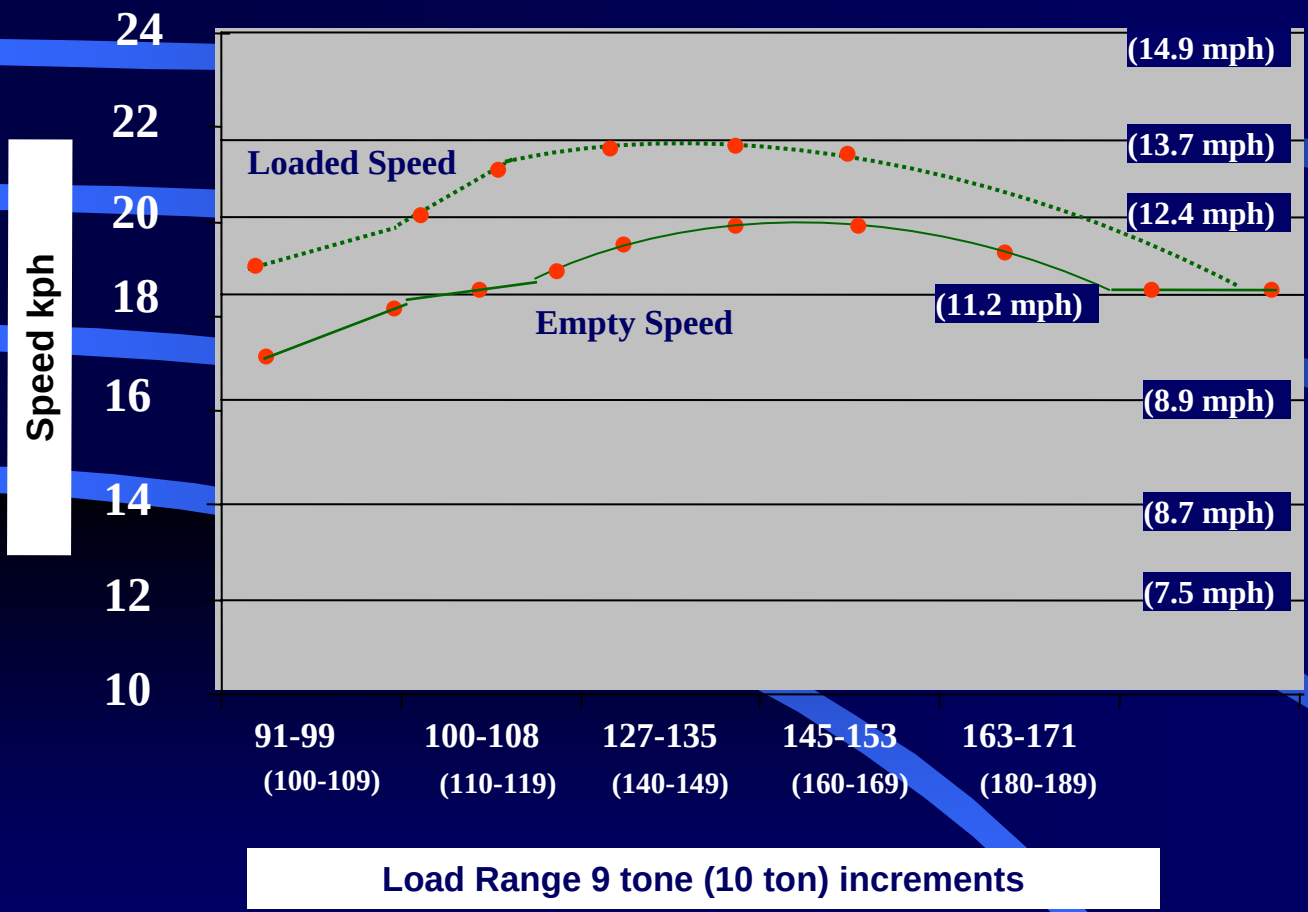
•It is also believed that the empty haul speed should remain constant due to this being a fixed weight condition.

•However, the results indicate a slight decrease 1.6km/h in the average empty speeds as the payload weight increased above 159Tons.

(Factors contributed to this is not known)

•It is interesting that haul and return speeds track each other across the range of operating loads.

Fig . 9 Speed Analysis for Day Shift, 1.6-1.8 km (1-1.1 ml) Haul Distance



Conclusions

Many factors influence a successful earthmoving operation.

The purpose of this study was to quantify the effects of payload weight on haul unit productivity.

Payload weight did appear to affect the incremental productive gain of the study fleet.

This is most evident as the payload weight approached or exceeded the rated capacity of the haul unit.

There was an obvious decrease in the slope of the production curves when the average payloads exceeds 150Tons (20 - 65% decreases)

From the 19,000 sideboards truck cycles, the average truck payload was increase by 6%; however it was not possible to quantity the exact effect of the increased truck capacity because two other factors came into play at the same time, increased truck availability and increased haul distance.

Management attention must be given to matching the number of bucket loads to fill a truck to an integer number, that satisfies both volumetric and gravimetric constraints.

The use of signal lights to indicate load limits may be causing an increase in loading duration.

Critique

- To analyze and interpret the effects of payload weight on fleet productivity and truck haulage economics.
- Computer data is of no value; it must be extracted and presented in a clear format so that earthmoving professionals who understand the physical process can discern the effects of their decisions.
- Cost perspective not discussed.
- Further study : sideboard effect.

Thank You !