Comparative Cost Evaluation Between Ten-wheel Trucks and Tractor & Semi-trailers

By

Kantipa Thamworrawrong

A PROJECT

Presented to the Faculty of Graduate School of
Computer and Engineering Management

In Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE
in
COMPUTER AND ENGINEERING MANAGEMENT
ASSUMPTION UNIVERSITY

December, 1998

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Project Title	Comparative Cost Evaluation Between Ten-Wheel Trucks and Tractor & Semi-Trailers *The tittle has been changed according to the final approval the committees
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The Graduate School of Assumption University has approved this final report of the three-credit course, CE 6998 Project, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

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ABSTRACT

This report concentrates on estimation of operating costs of 10-wheel truck and tractor & semi-trailer and analyze them with an engineering economic to select the better alternative among two types of truck. Steps in study: Firstly, the study is about transportation system in Thailand, the roles of truck in transportation system, and trend of 10-wheel truck and tractor & semi-trailer requirement in Thailand. Secondly, the study of the factors that affect operating cost of truck. Thirdly, the study of the estimating cost method of 1RRL (Transport and Road Research Laboratory) and apply this method to calculate operating cost of truck for Thailand condition. Fourthly, calculate operating cost of 10-wheel truck and tractor & semi-trailer with TRRL's method. Finally, analyze the operating cost of each truck with an engineering economic method, such as Net Present Value (NPV), Equivalent-Uniform-Annual-Worth (EUAW), etc., to select the better alternative.

The result shows that tractor & semi-trailers are more economical than 10-wheel trucks.

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I. INTRODUCTION

At present, transportation system is important to develop economics of country. The more civilized a country, the more facilities in transfer goods and travel, such as U.S.A , United Kingdom, etc. In Thailand, it has many modes of transportation. Example of modes are shown as follows:

Modes of Transportation and Quantity of Goods in Each Mode (Year 1994-1996)

Year	Quantity	Mode of transportation					
		Road	Train	River	Sea	Air	Total
1994	x 1000 tons	344,193	7,749	13,609	22,039	56	387,646
	Percentage	88.79	2.00	3.51	5.69	0.01	100.00
1995	x 1000 tons	383,261	7,815	12,739	19,998	69	423,882
	Percentage	90.42	1.84	3.01	4.72	0.02	100.00
1996	x 1000 tons	408,427	8,689	18,667	23,398	54	459,235
	Percentage	88.94	1.89	4.06	5.09	0.01	100.00

From data above, the road mode is the most popular. Truck is one type of vehicle that is important in road mode. It has a lot of advantages, such as flexibility, reliability, convenience, etc. But the main problem for truck is lack of data and good method to analyze its operating costs. So, it will be proper to find methods to calculate its operating costs for helping transportation companies to use this method for reducing total costs of companies.

Generally, there are two methods of transportation. They are as follows:

- Two Way Haul: There is load both in forward and backward routes.
- One Way Haul: There is load only forward route but no load on backward route.

In this report, it is about an engineering economic analysis for 10-wheel truck and tractor & semi-trailer. They will be assumed to be one way haul transportation. They will be analyzed and compared to find which type is more economical. In analyzing, an estimating cost method of TRRL (Transport and Road Research Laboratory) and an engineering economic method will be used to select the better alternative.

A_ Purposes

There are many purposes in this study as follows:

- Study factors that relate to estimate operating cost of truck.
- Introduce an estimating cost method of TRRL and an engineering economic method in analyzing truck.

B. Scope

There are many purposes in this study as follows:

- Study about 10-wheel truck and tractor & semi-trailer.
- Study an estimating cost method of TRRL and an engineering economic method.
- Analyze and compare 10-wheel truck and tractor & semi-trailer with the TRRL's method and the engineering economic method.

C. Steps in the Study

i. Investigate researches and study theories that relate to this topic.

ii. Study about data of truck in Thailand.

iii. Study details of 10-wheel truck and tractor & semi-trailer.

iv. Study methods to use in analyzing 10-wheel truck and tractor & semi-trailer (TRRL's method and engineering economic method).

v. Study factors that relate to calculate operating cost of truck for Thailand condition.

vi. Analyze 10-wheel truck and tractor & semi-trailer,

vii. Conclude and recommend the result of study.

D. Deliverables

The benefits are expected to obtain from studying:

- Successful in applying TRRL's method and engineering economic method to analyze truck.
- The results of this report can be used to be data in decision for investment of transportation companies.
- Introduce TRRL's method and engineering economic method widely.
- Apply these method for other vehicles.

II. **TRU**CKS

A truck is the automobile that has driven power in itself. It is used to carry and contain goods and transport them from one place to another.

Now, goods requirement increase rapidly, quality and type increasing. So, the transportation system should be developed. Truck is one type of important vehicles that used to transport goods.

A. Truck Classifications (nunisturiomun, 2540)

Trucks are classified by their gross vehicle weight (GVW) or weight of the vehicle and the weight of the load it can carry. There are three classes of light-duty trucks, three classes of medium-duty trucks, and two classes of heavy-duty trucks. A heavy-duty truck has a gross vehicle weight of 26,001 pounds or more.

Table 2.1. Truck Weight Classifications

Truck Weight Classifications		
Light-duty	Class 1	Up to 6,000 GVW'
	Class 2	6,001-10,000 GVW*
	Class 3	10,001-14,000 GVW*
Medium-duty	Class 4	14,001-16,000 GVW*
	Class 5	16,001-19,500 GVW*
	Class 6	19,501-26,000 GVW'
Heavy-duty	Class 7	26,001-33,000 GVW*
	Class 8	33,001 GVW* and over

* Gross Vehicle Weight in Pounds.

A truck is also classified by the number of axles it has. For example, a tractor with a tandem rear axle will be either a 6x2 or a 6x4. The first number in the designation refers to the total number of wheels (or sets of wheels in the case of dual wheels) and the second number indicates the number of wheels that are driven by the power train. A tractor with a tandem rear where only the front rear axle is driven would be a 6x2; it has 6 wheels but only 2 wheels drive the vehicle. Table 2.2 lists the common axle wheel designations and the applicable driven wheels and axles.

Table 2.2_ Truck Classification by Wheel Number

Truck Classification by Wheel Number				
Motor Vehicle	Total Wheels	Driven Wheels	Total Axles	Driven Axles
4x2	4	2	2	1
4x4	4	4	2	2
6x2	6	2	3	1
6x4	6	4	3	2
6x6	6	6	3	3
8x4	8	4	4	2
8x8	8	8	4	4

A crucial consideration in determining tractor & semi-trailer dimensions is the relationship between the two vehicles when coupled together. There must be enough space between the tractor cab and semi-trailer front, as well as between the rear of the tractor and semi-trailer landing gear assembly, to allow for sharp turns and the effect of grade changes.

B. Trucks System (nDln171111d111111111, 2540)

- Engines. Trucks are powered exclusively by diesel engines. The diesel is more economical to operate, more dependable, requires less downtime for repairs and is capable of generating more power and torque than a gasoline engine. Many new diesel engines are electronically controlled to maximize power output while minimizing emission levels. In addition, various engine support systems-air induction, fuel injection, exhaust, lubrication, and cooling-work together to keep the engine running properly.

- Electrical Systems. The batteries, alternator, and starter must be sized to match the operating requirements of the engine and truck electrical systems. Most heavy-duty trucks have two to four batteries to supply the current needed for the starter. Some trucks have 24 volt starters that require a series/parallel switch in the system. In addition, the electrical systems of trucks provide power to operate such safety components as lighting, windshield wiper motors gauges, plus the operation of the desirable accessories.

- Clutches. Trucks will use either a push- or pull-type clutch. Those trucks equipped with high torque engines and designed to haul heavy payloads will use a two-plate clutch. The additional contact surface is necessary to transmit the high torque to the transmission without slippage.

- Transmissions. Truck transmissions are complex pieces of machinery and it is a tribute to materials, engineers, production workers, and truck technicians that trines can last as long as they do. Their gears, shafts, bearings, forks, and other parts go through their paces for thousands of hours, hundreds of thousands of miles, year after

year. It is not unusual for a modern Class 8 transmission to run for a half-million miles with little maintenance other than paying heed to lubricant levels and drain intervals.

The majority of trucks are equipped with standard transmission. Depending on the engine output, the intended application of the vehicle, and the terrain over which it must operate, the transmission might have six to fifteen forward gears. These transmissions have two or three countershafts that transmit the engine torque from the input shaft to the output shaft (main shaft). This splits the torque two or three ways so that there is less strain on individual gears, prolonging the service life of the transmission.

Although the days of the big bore, naturally aspirated diesels-with their narrow rpm range requiring multispeed transmissions-are gone, 12-,13-,15-,18-, and 20- speed transmissions are still popular with drivers. Transmissions with many speeds are more likely to offer the perfect ration in any given situation. By skip-shifting where appropriate, a skilled driver can equal or better the fuel economy attainable with a 7- or 9-speed transmission while extracting better performance from the engine.

- Drive Shafts. A companion flange or end yoke connected to the output shaft of the transmission transfers engine torque to the drive shaft The drive shaft is a hollow tube with end yokes welded or splined to each end. Splined yokes allow the drive shaft to increase in length to accommodate movements of the drive axles. Sections of the drive shaft are connected to each other and to the transmission and differentials with universal joints. The Ujoints allow torque to be transmitted to components that are operating at different angles.

- Axles. Axles provide a mounting point for the suspension system components, wheels, and steering components. The drive axles also carry the differential and axle shafts. The differential transfers the motion of the drive shaft, which is turning perpendicular to the rotation of the axle shaft, into motion that is

parallel with the direction the vehicle is moving. A differential also provides a gear reduction, increasing the torque value delivered to the drive wheels. A differential also allows torque to be divided between the left and right wheels. This torque differentiation varies between the inside and outside wheels during a turn or when negotiating a curve; the outside wheel is permitted to turn faster than the inside wheel.

- Steering. Both standard and power steering systems are installed on trucks. Two types of manual steering gears are used; worm and roller and recirculating ball. In most cases, a pitman arm and drag link connect the steering gear to a steering arm and knuckle. A tie-rod connects the two steering knuckles. Power steering systems use a hydraulic pump to provide steering assist to a recirculating ball-type gear. Steering assist can also be provided by and air-powered cylinder installed in the steering linkage.
- Wheels and Tires. There are four basic types of wheel systems;
  - cast spoke.
  - steel disc.
  - aluminum disc.
  - wide-base disc.
- Brakes. Service brakes are perhaps the most important system on a vehicle. If they do not function properly, a serious accident could occur. Even if they perform well, brake systems can lead to major repair costs if they wear out prematurely.

Trucks use air service brakes exclusively, An extensive arrangement of pneumatic lines, valves, and cylinders controls the delivery of compressed air to the foundation brakes. Trucks are equipped with S-cam brakes, wedge-type drum brakes, or disc brakes.

- Suspension Systems. Smooth-riding axle air suspensions are popular for reasons of comfort and cargo protection. But while truckers and the payload benefit, so does the vehicle itself. Makers of air suspension point to fleet experience of reduced maintenance on trucks and trailers equipped with air suspension, which absorbs more road shock than conventional spring suspensions.

Another advantage of air suspension is better axle control, which makes its use ideal for low-profile, high-cube applications where tire-to-body clearance is tight. Ride and handling are much improved when running empty., as air suspension maintains the same ride height regardless of gross vehicle weight. Air springs are also commonly used for liftable tag and pusher axles; the loading of which can be precisely controlled by varying air pressure.

Like axle air suspension, cab air suspension systems are getting more popular and for some of the same reasons. By minimizing vibration transmitted to the cab, they reduce repairs to cab hardware and electrical components. They also reduce driver fatigue and can easily add enough to resale value to cover their original price.

- Vehicle Retarders. There are a variety of ways to slow down a moving tractor/trailer without engaging the service brakes. The most popular vehicle retarder is the engine brake; it turns the engine into a compressor and uses compressed airing the combustion chamber to slow the engine. An exhaust brake creates a restriction in the exhaust system to slow the engine and truck. Some vehicles, particularly those equipped with an automatic transmission, use a hydraulic retarder to reduce vehicle speed. A fourth type of retarder is the electrical retarder, which uses magnetism to resist the rotation of the power train.

- Fifth Wheel. A fifth wheel is used on a tractor/trailer combination to connect the tractor to the trailer's kingpin. The weight of the trailer rests on the pad of the fifth wheel and the truck pivots around the kingpin when turning corners or rounding curves. Various locking mechanisms are used to fasten the kingpin to the fifth wheels. And most fifth wheels can be slid backward or forward to properly position the weight of the trailer on the tractor.

- Electronic Controls. The invasion of electronics into the trucking industry will change trucking significantly. Primarily, service technicians will have to adapt to the changing environment by learning about electronics and their applications on trucks. Voice commands, navigation systems, and physiological measurements (for example, drowsiness) will dramatically change the way the driver operates the vehicle. These innovations are not science fiction or some futuristic technology but are in the immediate future of the trucking industry. Actually, electronic control systems provide design flexibility that no mechanical system can match. Electronic systems can be readily adapted to different truck configuration. This can require only a gain adjustment or program change and can result in significantly lower inventory levels (fewer part numbers). Electronics can be packages to suit the truck, located for optimum installation and service convenience and for protection from the environment.

- Accessories. There are several safety and driver comfort accessories that can be found on a truck. If the truck technician is responsible for their serving ,the necessary information can be found in the manufacturer's service manual.

Driver Seats, The driver's seat, perhaps more than any other accessory component, is key to improving driver comfort and reducing fatigue and stress. Truck seats are offered in three basic types-mechanically suspended, pneumatically (air) suspended, and solid-mounted. The later, as the name implies, has no suspension

system to absorb road bounce, shock, and vibration. Suspension seats use a free-moving support system to keep the driver from taking the full brunt of the jolts coming through the chassis to the cab.

Air suspension seats do this with an air bag/cushion and shock absorber assembly, with compressed air drawn from the vehicle's air system. Mechanical-suspension seats use a spring assembly.

Optional seat accessories are available to enhance a driver comfort and ride. Plus make for a more pleasing appearance. These include adjustable armrests, adjustable headrests, various densities of seat cushion foam, molded seat cushions, automatic weight adjustment, complete seat lowering for easier exit and entry, and suspension covers/bellows. Typical seat adjustments, include the following:

- Height/Weight. Raises or lower the seat.
- Fore and Aft. Slides seat forward or rearward.
- Fore and Aft Isolator. Controls "back slap" (fore and aft pitch movement) and "kidney punch."
- Seat Cushion Tilt/Length. Allows height, angle, and length adjustment of the seat bottom cushion
- Seat Back \Angle/R.ecliner. Moves seat back forward or rearward.
- Lumbar Support. Increases or decreases the support in the lumbar (lower back) area.

There are three main styles of driver seats: low back, intermediate back, and high back. Some suspension seats come in low-profile models for use in cabs where leg or head room is limited. Many seats offer integrated three-point (lap and diagonal) seat belts in either suspended or fixed form.

- Sleepers. Sleepers are a necessary item on linehaul tractors, which spend more than a day away from home. Early models were barely adequate to sleep one man comfortably, but today's units are generally more spacious and much more luxurious. Most truck manufacturers offer their own sleeper models for both cabover and conventional cabs. They come in set sizes and can be ordered in different trim levels. Unitized construction (when the cab and the sleeper are made as one unit) is virtually standard on cabovers and a number of truck builders are now also offering it on conventional. This design is stronger and more stable than the traditional sleeper box and places fewer stresses on the cab framework. It also offers more interior room, allowing easier access to the sleeper from the cab. Higher versions also provide enough room for double bunks and sufficient headroom for the driver/co-driver to stand up in the sleeper compartment. For drivers desiring a veritable "home away from home", after market manufacturers can build a sleeper to almost any dimensions and fit it out with options such as TV, VCR, refrigerator, microwave, generator, a shower, and -naturally- the kitchen sink.

Two primary in-truck features are premium sound systems for both cab and sleeper, and television systems for the sleeper unit. The basic sound system consists of AM/FM radio with cassette player. Speakers must be selected based upon the type of music preferred. Configuration of the cab or sleeper interior, and frequency of system use. Components can then be added: a graphic equalizer, for example, improves quality of the sound by controlling the volume of each frequency range, letting the driver balance, or equalize, various sound levels to individual preference.

- CB Radios, In-Cab (Cellular) Phones, and Accessories. Being confined to the cab for hundreds of miles at a time can be draining But the CB radio or cellular phone can put the trucker in touch with the outside world. The CB keeps drivers in tune

with one another and is often their primary source of information regarding weather and road conditions, medical and the emergencies, and local and state police actions. Chief features of the CB that count for more than just convenience are microphone gain control (boosts your sound to others), noise "blander" switch (cuts background interference), and a dual level display (adjusts for daytime/nighttime conditions).

The cellular phone, mounted in-cab, is in a quiet way revolutionizing the customs of drivers. When drivers are in areas containing a cell (transmitting unit), they can phone just about anywhere. Calls to customers, dispatchers, and spouses, which normally require pulling off the road and locating both parking and a phone, can be made on the go, and become routine, Accessories for both CBs and cellular phones include antennas and roof mounts.

- Heating/Air Conditioning. Vehicle builders usually engineer their own integral systems using supplier components, which may function fine but may be difficult to service. Add on systems, by contrast, offer cost savings in initial price and are easier to maintain but may not circulate air around the cab as effectively, Electrically powered auxiliary heater/air conditioners eliminate expensive engine idling during overnight stops. Fans or blower systems directing currents of air at the driver and on the windshield are inexpensive complements to the vehicle's existing built-in climate controls.

- Radar Detectors. As controversial as their use may be, radar detectors have never been more popular. That is because the technology behind them continues to grow in sophistication, providing more elaborate features in more compact, or readily disguised, formats. Most truckers claim they use the devices not to speed, but to keep themselves aware of speed enforcement and to give them a fair chance against unwanted tickets. The basic function of any unit is to provide adequate warning of the

presence of radar waves. Features vary, but most want a unit that screens out unwanted signals and can differentiate between these and the real thing. It must be remembered that several state regulations do not permit the use of radar detectors.

- Engine Speed Controls. Cruise control allows a steady road speed to relieve driver fatigue and encourage economical speeds. Electronic engine controls, working through minicomputers, precisely measure fuel for better economy and cleaner exhaust. Electronics also govern engine speed without the "droop", or overrun, characteristic of some mechanical governors: determine the engine's power and torque output facilitate quick diagnosis of problems, and allow auxiliary functions like road speed governing, cruise control and power take-off operation. Electronic controls are either optional or standard on many truck diesels.

- Engine and Fuel Heaters. Engine preheaters provide fast starts on cold mornings, eliminating frustration and cutting engine wear. Some models are electric, requiring external plug-in or auxiliary power, while gasoline-or diesel-fired heaters run off vehicle fuel. Fuel heater/water separator units provide clean, water-free fuel to the engine. That means keeping fuel free of frozen or clouded wax crystals caused by cold temperatures and water that forms in poor quality fuel. Separators strip water out of the fuel, while in-tank and on-line heaters keep it flowing in a steady stream to its destination the engine.

- Air Horns. Horns are supplied as standard by all manufacturers of truck vehicles. But every trucker knows whether or not they are adequate and, if additional horns are needed, where they should be place.

- Instrument Panels. Such instrument panel devices as temperature gauges, pyrometers, shut down systems, and turbo boost gauges do more than provide the driver with valuable information. By allowing the driver to track the performance of various

vehicle systems, they help create a safer driving environment for the driver and the vehicle.

- Auxiliary Power Units. APU's are favoured by truckers everywhere because they do so much for so little. Their cost is relatively low, their size and weight are minimal, and noise is generally not a factor. They can be used to keep truck and engine warm while powering other features in the cab and sleeper.

- Lighting Systems. Although it is so crucial to see and be seen, lighting is a continuous source of complaints by drivers. Today, contoured plastic lenses and reflectors meet styling and aerodynamic needs while giving better impact resistance than glass. Drivers find replaceable halogen bulbs easier to carry and install than entire headlight units, and the durability of these bulbs is being improved for truck applications, But there is more to vehicle lighting than headlights. Marker lights and tail lights have been changing and improving too. The biggest advance, in recent years has been that of sealed-housing lamps with shock-mounted bulbs. This design secures bulb contact and lengthens life by combating the two biggest killers of lighting assemblies; corrosion and vibration (At least one manufacturer has taken a "backward" step with a replaceable tail light that features shock mounting, no screws, and long filament life.).

Light, of course, are no better than the wiring and connectors that serve them. Wiring harness repair parts may all look the same, but proper materials and repair methods make all the difference in how long the repair lasts. Dielectrics (nonconducting) greases, sealant-coated shrink tubing, and connectors with 0-rings are just some of the "tricks" that can keep trucks from reappearing in the shop once repaired. In fact, specifying good quality wiring and lighting components is probably the best way to keep them out of the shop in the first place.

- Paint. The type of paint selected is as critical as its colour, and durability is a key factor. Extra-tough Urethane and other compounds are available, and cost more initially, But they are tougher, last longer, and look better, and so can pay for themselves. Truck builders offer specialty paint schemes of their own which are specified at the time the truck is purchased. When it comes time for touch-up work and repainting, local shops can handle these tasks, with a variety of truck paints at their disposal.

- Chrome Accessories. It may be that chrome never moved an ounce of freight, but it is also true that happy drivers move more freight than unhappy one. And most drivers like chrome. But, chrome accessories are no longer considered mere decoration of the truck's exterior. Fuel tanks, hubcaps, mirror heads, steps, grab rails, and more can be found in bright, durable chrome. These functional utilities help the trucker do the job in a vehicle noted for its bright "look." Like chrome, polished aluminium is a popular material for many accessories because it is tough, durable, and gives the truck a distinctive image.

- Level of Truck Industry can be divided into 3 levels as follows:

  - Semi Knocked Down (S.K.D.). In this step; completed body, engine, and accessories of truck will be imported from supplier in foreign countries. The employees of factory in own country will fit these components together to become truck only because employees have no skill and experience. The employees will be trained to increase skill and experience until they have enough skill and experience. This step may be called the start point.

  - Completely Knocked Down (C.K.D.). In this step; the employees have more skill and experience than the first step. Components that imported from supplier in foreign country, will be parts of truck such as chassis, sub parts of

body. The employees will fit and join these component with engine and accessories to be truck. The employees will be trained for more skill and experience. The special tools and techniques must be used in this step.

- National Autonomy in Tooling and Vehicle Research. In this step; the employees will have more and more skill and experience. Every parts of truck can be produced and special tools, engines, and accessories can be developed in own country. Truck can be produced in own coimtry. So, the factories in own country will become to new suppliers_

• Domestic Production of Truck Bodies and Semi-trailers. There is a large number of truck body builders, large and small, located throughout the country. While there is much variation, basically there are two types of body: wooden and steel.

- Wooden Bodies. These are the commonest body type, especially for long haul bagged agricultural products. They are built of hardwood, and last for a minimum of ten years. They are permitted to be built up to a legal maximum height of 3.80 m, but often exceed this. They have two disadvantages:

i. The high side wooden bodies are heavier than the standard non-tipping steel bodies by 0.5 ton, which added to tare weight reduces payload at legal GVW limits.

ii. They cost about 70,000 baht some 40% more than steel bodies, but the extra cost is offset by their longer life.

- Steel Bodies. These usually have a life of 5-7 years, and are used extensively in the construction industry, where rough usage is common.

- Tip Trucks. Tip trucks can be constructed of wood or steel. The weight of the tip mechanism adds about 0.5 ton to tare weight.

- Trailers and Semi-trailers. These are produced domestically, but unlike truck assembly, no data are available on the numbers produced annually. One gave an estimate of total trailer and semi-trailer sales over the four years 1982 to 1985 of 1800, of which about 1000 were imported. The market is small, and trailer manufacturers are also body-builders and makers of vehicle components. Some trailer producers use old axles, and some produce trailers from old truck chassis. Most use imported turn-table, pintle hooks and fifth wheels, The average financial cost of steel trailers using new components is about 250,000 baht. Wooden trailers are about 10% more. Tip trailers cost about 10,000 baht more than non-tip.

C. Trends of Truck Requirements

The comparison between the state of truck technology in Thailand and improvements in technology world-wide must be based on realities, and not on theoretical approaches. The realities are as follows:

- Improvements in Technology. Basic improvements can only be obtained through investment in new trucks, either domestically assembled or imported.
- The Scope for Improvement. The dominant truck type in Thailand is the 10 - wheel truck. Both the load factor and efficiency of this type of truck could be improved by modifying the models being assembled. Furthermore 10 - wheel truck models could be converted to tow full trailers, or to serve as tractor heads for semi-trailers. At present their use in these two latter roles is relatively insignificant. Land transport department origin and destination surveys record that on the 6 major routes

into and out of Bangkok (which carry 21% of total road freight) 15% of total tonnage was carried by 6 wheel trucks, 80% by 10 wheel trucks, and 5% by truck-trailers and semi-trailers. Outside of this origin and destination network has located definitively another 40% of total road freight, comprising bulk agricultural commodities and construction materials, all carried by 10 - wheel trucks. Within the Greater Bangkok area the role of truck-trailers and semi-trailers appears to be growing at a faster rate, both in the role of container transport, and in the transport of petroleum products. The records of Express-way&Rapid Transit Authority of Thailand, 1985, show that on the Express-way, 5% of total truck traffic consisted of these types.

- The 10 - Wheel Truck Fleet. From estimated data; it shows that in 1986 this fleet totalled 63,000, Its average age is 10 years (3 years above the European scrapping age), and it is functioning at various degrees of efficiency. Keeping old trucks running has two advantages:

  - Capital resources needed to replace old trucks are kept to a minimum
  - Truck operating costs (TOC) are reduced by the elimination of the annual capital cost (ACC), which is reflected in lowered freight rates.

A disadvantage is that old trucks are liable to lower utilization, and old models have higher fuel consumption, unless engines have been changed for newer and more fuel efficient models.

- Sunk Investment. The 63,000 10 - wheel trucks represent a large investment over the last 22 years_ It this investment is discounted back year by year for the numbers of new trucks at the present value of 730,000 baht for the average financial sales price of a 10 - wheel truck with body, at a discount rate of 17%, the net present value of the flee is 21,800 million in financial sales price. Similarly if the average economic cost is discounted back at 12%, the net present economic cost of the fleet is 19,000 million.

These are sunk investments on a very large scale, and they are being eroded at an estimated rate of only 2.0% a year.

- The Truck Market.

  - Replacement. The wastage rate should increase over time, as old trucks cannot be kept alive forever by the constant replacement of second-hand engines, and the wastage rate could rise to 5% over the period to 1993.

    Thus the replacement market could rise from an estimated 1,300 trucks in 1987 to 3,200 in 1993.

  — Additional Demand. The demand / supply situation in road freight transport and the growth of the 10-wheel truck fleet indicate that to 1983, the supply of trucks exceeded demand, resulting in and over-supply situation. Since 1983 supply has rapidly diminished, but will probably not match demand until 1988. Projections of demand to 1993 indicate a slow down of demand in those sections of the economy which have historically generated the rapid growth of 10 - wheel truck transport, notably in the bulk transport of agricultural products, and in the construction industry. These in the past accounted for at least 60% of total road freight demand. To 1993 the long-haul transport of agricultural products is expected to grow by an annual average compound growth rate of L5%, instead of 2.7%, and the short-haul transport of construction materials by 5%, instead of 8%. Thus additional demand from 1988 to 1993 for 10 wheel truck transport can be expected to grow, at most, by 3% annually, i.e. about 2,000 trucks a year.

  - Total Demand. The market for 10 - wheel truck sales can be expected to be as follows: (110.9511f1151=fllIllitIG41-1, 2529 LL w,' flailfiflThinflD4114U41-1, 2530)

Table 2.3. The Projected Market for 10 - Wheel Truck Sales 1987-1993

	Year						
	1987	1988	1989	1990	1991	1992	1993
Replacement	1,300	1,510	1,755	2,040	2,370	2,760	3,200
Additional Demand	-	2,000	2,000	2,000	2,000	2,000	2,000
Total	1,300	3,510	3,755	4,040	4,370	4,760	5,200

This is the extent of the market in which improved 10 wheel trucks, and 10 - wheel trucks for towing trailers can be initiated and generated, apart from increase container traffic.

In forecasting truck requirement, the past data of its requirement is necessary to use in forecasting the requirement in the future. The technique is advised to be the linear regression technique. The past data are obtained from Ministry of Transportation and Communication in year 1980 to 1986.

Table 2.4. The Past Data of Truck Requirement in year 1980 - 1986

Year	Truck Requirement (Cars)
1980	139,023
1981	156,054
1982	163,866
1983	171,235
1984	181,959
1985	190,047
1986	198,883

The linear regression formula:

$$Y = a + bX$$

given:

The quantity of Truck (Cars)

$$X = Year$$

a: = Constant

Constant

$$b = \frac{nEXY—EXEY}{nE\ X^2—(EX)^2}$$

$$a = EY—b1X$$

Correlation Coefficient (r) and Coefficient of Determination (r^2)

$$r — \frac{nIXY—EXEY}{v[nEx2—(Ex)2][nEY2 - (Y)]}$$

Year	X	Truck Requirement (Cars) Y	X^2	XY
1980	1	139,023	1	139,023
1981	2	156,054	4	312,108
1982	3	163,866	9	491,598
1983	4	171,235	16	684,940
1984	5	181,959	25	909,795
1985	6	190,047	36	1,140,282
1986	7	198,883	49	1,392,181
Total	28	1,201,067	140	5,069,927

$$b = \frac{nEXY - EXEY}{nEX^2 - (Z\ X)^2}$$, n = 7

9,487.821

$$a = \frac{EY}{} - b1X$$

a = 133,629.7

$$r = \frac{nExy\text{-}ExEy}{V[nEx^2 \text{--}(Ex)^2\ linEy^2 - (Ey)^2 1}$$

r = 0.99326

r^2 = 0.9865 ; nearly 1, So the data are accept.

$$Y = 133{,}629.7 + 9{,}487.821X$$

The expect of quantity of truck in year 1987 to 2000 can be calculated as follows:

Year	X	Truck requirement (Cars) y = 133,629.7 + 9,487.821X
1987	8	209,533
1988	9	219,021
1989	10	228,508
1990	11	237,996
1991	12	247,484
1992	13	256,972
1993	14	266,460
1994	15	275,947
1995	16	285,435
1996	17	294,923
1997	18	304,411
1998	19	313,899
1999	20	323,387
2000	21	332,874

D. Operating Cost (Trader's view)

Operating cost is divided into two parts: Running costs and Standing costs. Details of each part can discussed as follows:

Running costs consist of:

- Fuel consumption.
- Vehicle maintenance labour hours.
- Vehicle depreciation.
- Vehicle maintenance parts consumption.
- Lubricating oil consumption.
- Tire consumption.
- Crew hours.

Standing costs is about 25% of Running costs.

E. Factors in Considering Operation Cost

- Rise and Fall of road (RS,F).
- Vehicle speed (V).
- Power to weight ratio (PW).
- Gross Vehicle Weight (GVW).
- Roughness of road (R).
- Cumulative kilometres (K).
- Average annual kilometres (KA).

- Vehicle age in years or Life Time.
- Vehicle price (VP).

In this report, The 10-wheel truck and semi-trailer will be discussed and analyzed in economics for trader view.

III. THE 10-WHEEL TRUCK

A 10-wheel truck is one type of truck. It is in heavy duty truck type. It is used for containing and transporting the goods.

A. Components of 10-Wheel Truck (1711f1159114rionzun, 2540)

- Hydraulic Oil Tank.
- Electrical 7-plugs.
- Coupling,
- Air tank (30 liters).
- Mini relay valve.
- Three ways control valve.
- Oil pump gear.
- Hydraulic gear_
- Two ways valve.
- Driven pump axle.
- Power take off unit,
- Pressure gauge.
- Hand brake valve.
- Control valve handle.
- Power take off handle.
- Pump handle.
- Lock switch.

- Light signal.

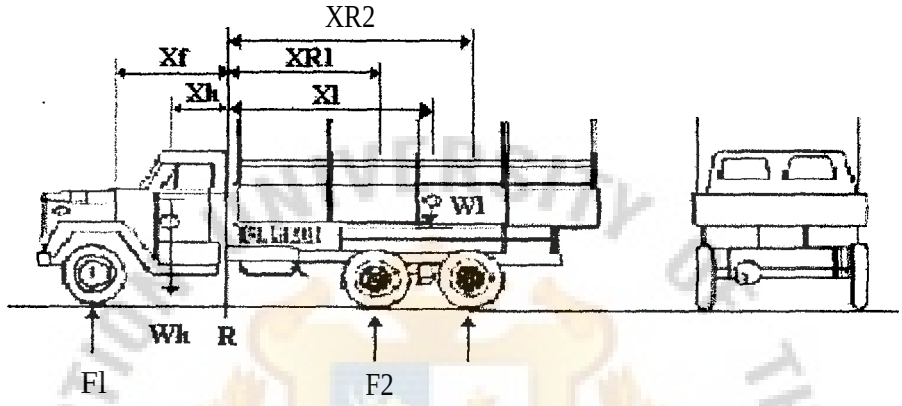
B. <u>Production of 10-Wheel Body.</u> (fininniudsiniun, 2540)

In producing 10-wheel trucks; there are two basic types of body : wooden and steel. The detail of each type will be shown as follows:

- Wooden Bodies. These are the commonest body type, especially for long haul bagged agricultural products. They are built of hardwood, and last for a minimum of 10 years. They are permitted to be built up to a legal maximum height of 3.80 in., but often exceed this. They have two disadvantages:
  - The high side wooded bodies are heavier than the standard non-tipping steel bodies by 0.5 ton, which added to tare weight reduces payload at legal GVW limits.
  - Their cost are about 90,000 baht, some 40% more than steel bodies, but the extra cost is offset by their longer life.
- Steel Bodies. These usually have a life of 5-7 years, and are used extensively in the construction industry, where rough usage is common.

C. Distribution Force (nv4innimm.,n1I'INLIF11,1, 2531 u AVslivin milM;nivailtim,t, 2532)

The 10-wheel truck is the three axles- tandem axle, double tires type truck. Distribution of forces will be shown in figure 3.1.



Wh = The weight of head (kg.).

W_I = The weight of load (kg.).

F1 = The reaction force at front axle (kg.).

F2 = The reaction force at rear axle No.1 (kg.).

F_3 = The reaction force at rear axle No.2 (kg.).

Reference point.

X_h = Distant from R to Wh (meters).

Distant from R to W_I (meters).

XF = Distant from R to F_1 (meters).

X_{RI} Distant from R to F_2 (meters).

X_{R2} = Distant from R to F_3 (meters),

Figure 3.1. Distribution Force of 10-wheel Truck

Formula;

WhXh F2XR1 F3XR2 W1X1 F1XF

Wh + WI = F1 + F2 + F3

D. <u>10 -Wheel Truck Requirement</u> NA-a, 2526)

Year 1965;

The total number of 10-wheel trucks are 2,193 cars.

Year 1965-1970;

The total number of 10-wheel trucks are 11,338 cars.

Year 1970-1975;

The total number of 10-wheel trucks are 19,563 cars.

Year 1975-1978;

The number of 10-wheel trucks in Bangkok are	3,722 cars
The number of 10-wheel trucks in other areas are	26,390 cars
Total	30,112 cars
% Bangkok	12.4 %
% Other areas	87.6 %

Year 1978-1985; The total number of 10-wheel trucks are 59,818 cars.

The number of 10-wheel trucks in Bangkok are	6,706 cars
The number of 10-wheel trucks in other areas are	52,676 cars

Total	59,818 cars
% Bangkok	11.3 %
% Other areas	88.7 %

Type of goods that be transported by 10-wheel truck can be divided into many segmented as follows:

- Tankers: Petroleum products, molasses and other liquefied products and ready-mix concrete.
- Sand and Crushed Rock: These are used together with cement in the production of concrete.
- Sugar Cane.
- Log.
- Minerals: Most of them are Gypsum and Fluorite.

E. Operating Cost (Trader's view)

Operating cost is divided into two parts: Running costs and Standing costs. Details of each part can discussed as follow:

Running costs consist of:

- Fuel consumption.
- Lubricating oil consumption.
- Vehicle maintenance parts consumption.

- Vehicle maintenance labour hours.
- Tire consumption.
- Vehicle depreciation.
- Crew hours.

Standing costs is about 25% of Running costs.

F. Factors in Considering Operation Cost

- Rise and Fall of road (RS,F).
- Vehicle speed (V).
- Power to weight ratio (PW).
- Gross Vehicle Weight (GVW).
- Roughness of road (R).
- Cumulative kilometres (K).
- Average annual kilometres (KA).
- Vehicle age in years or Life Time.
- Vehicle price (VP),

IV. THE TRACTOR AND SEMI-TRAILER

Tractor is one type of truck. It is an automobile that not uses to contain anything like other truck. It is used to drag other automobile that no driven power in itself such as semi-trailer, trailer.

Semi-trailer is automobile that no driven power in itself It can move by tractor. The all load of semi-trailer will not be on its axle. Part of load will be on tandem axle of tractor and another part of load will be on its axle.

A. Advantages In Using Tractor And Semi-Trailer In Transportation (fI1lJninudoliun, 2540)

- Increase efficiency in transportation system.

  - Save time in loading and unloading.

  - Good in resource allocation: tractor can be use all time.

  - Save cost: because one tractor can be use with many semi-trailers.

- Tractor and semi-trailer can contain goods more than truck in each trip.

- Suitable for special size goods or equipment:

  - Large size machine.

  - Long size iron pipe, iron wire, log, concrete beam, electrical post, etc.

  - Container transportation.

B. Related Factors In Tractor And Semi-Trailer Transportation (f151.1=111,4011111fl, 2540)

It means factors that trader must consider in using tractor and semi-trailer in transportation for the most efficient and the optimal number of cars.

- Quantity or number of trips in transportation.
  - Optimal number of trips.
  - Optimal number of tractors and semi-trailers.
- Route and road condition.
  - To select type of tractor and semi-trailer.
  - To select size of tractor and semi-trailer_
  - To select power of tractor and semi-trailer.
- Load & unload point and facilitation system.
  - To design proper warehouse.
  - To design proper loading and unloading points.
  - To design proper material handling: such as folk lift, crane, etc.
- Transportation system planning.
  - Efficiency in resource allocation.
  - Reduce number of trips in transportation, it is cause to reduce cost.
  - Reduce risk in transportation, because of fewer trips.
  - Complete task in time.

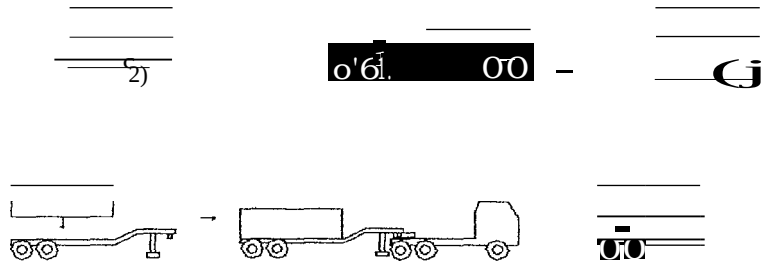


Figure 4.1. Tractor & Semi-trailer

C. A tractor (n11.11115111iiorisnin, 2540)

It is used to drag semi-trailer. Its loading point is on the fifth wheel. Some part of load on semi-trailer will be supported by tractor and other will be supported by tandem axle of semi-trailer.

Type of tractors

i. Divide by tandem axle.

- 4x2 tandem axle.

- 6x4 tandem axle.

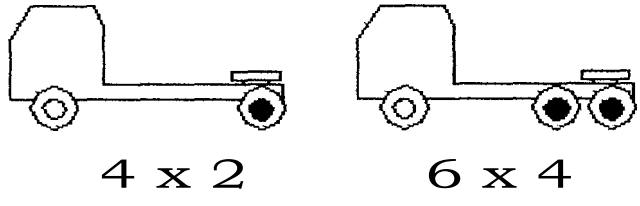


Figure 4.2. Tractor

Divide by axle of the fifth wheel.

- Single axle.

- Two axle.

iii. Divide by tandem axle.

- Forward control.

- Normal control.

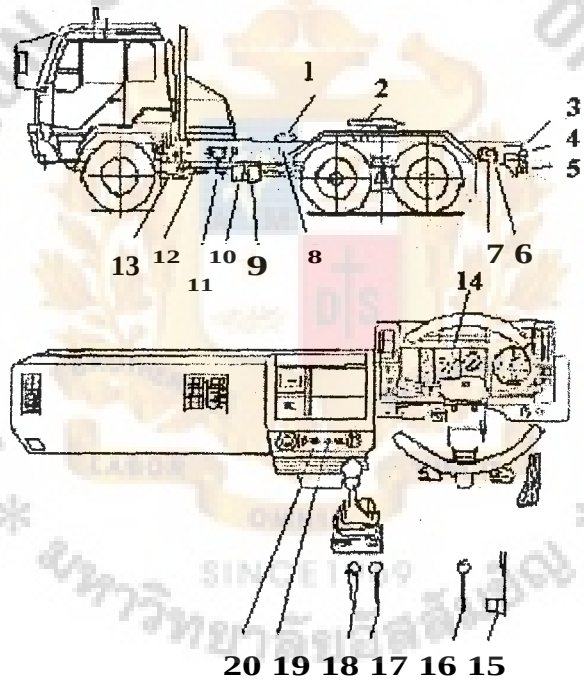


Figure 4.3. Equipment of Tractor

- The notations for Figure 4.3:

  No.1 Hydraulic Oil Tank.

  No.2 The fifth wheel.

  – No.3 Electrical 7-plugs.

- No.4 Coupling.
- No.5 Rockinger_
- No.6 Air tank (30 liters).
- No.7 Mini relay valve.

No.8 Three ways control valve.

- No.9 Oil pump gear.
- No.10 Hydraulic gear.
- No.11 Two ways valve.
- No.12 Driven pump axle.
- No.13 Power take off unit.
- No.14 Pressure gauge.
- No.15 Hand brake valve.
- No.16 Control valve handle.
- No.17 Power take off handle.
- No.18 Pump handle.
— No.19 Lock switch.
- No.20 Light signal.

Maximum load of tractor

- Tractor: type 2 axles, Double tires at rear axle, Maximum load: 12 tons,
- Tractor: type 3 axles, Double tires at rear -axle, Maximum load: 21 tons.

D. A Semi-Trailer (nuni5-ini nisrun, 2540)

Semi-trailer can be divided into four types as follows:

- Container Chassis Semi-trailer. It uses a container. That can reduce damage of goods, store quality of goods, etc. In using semi-trailer in this method, it is one method to develop transportation system into international system because container is the standard in transportation system of many countries in the world.

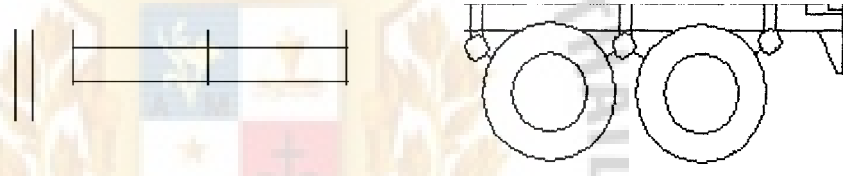


Figure 4,4. Container Chassis Semi-trailer

Type of goods that can transfer with container chassis semi-trailer.

- Industrial goods. Because industrial goods is easy to fragile and have standard packaging.

The advantages of this method are:

i. To reduce damage during transfer goods.

ii. To reduce loss space in containing goods into container.

iii. To easy in transfer goods.

Example of goods: Television, radio, glass, roof tile, and log.

- Agricultural goods. Because agricultural goods is easy to decay and quality of them is importance. This method can reduce time and control proper temperature for them.

Example of goods: Vegetable, fruit, corn, and wheat.

- Freezing goods. Because this type of goods is easy to decay, the control temperature system is necessary for them. This method can prepare refrigerated system within container.

Example of goods: Meat, pork, and seafood.

- Export Agricultural goods. At present, many agricultural goods (mango, cabbage, white green, lettuce, etc.) can be exported to foreign: Europe, America, Asia; so, the good packaging is important to protect goods. This method can support in this purpose.

- Flat Bed Semi-trailer. It is used for container, the goods that body side is not necessary. The goods do not leave out during transferring and easy to transfer.

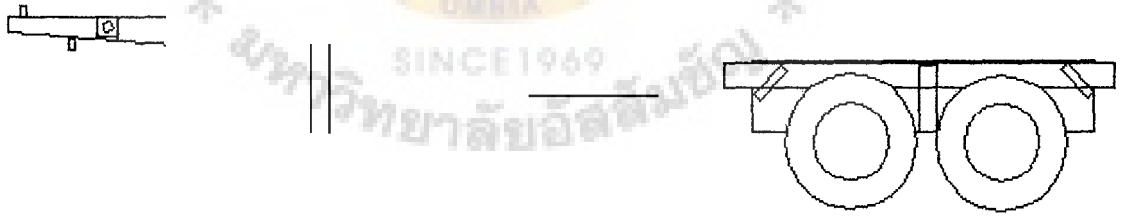


Figure 4.5. Flat Bed Semi-trailer

Example of goods:

- Cement product: cement powder, cement beam, cement foundation pile.

- Civil Metal: iron sheet, iron plate, iron wire, iron pipe, wire.

- Civil Material: glass, sanitary ware.

- Wood Product: rock, wooden door, and wooden window.

- Beverage: beer, whiskey, vine, water, syrup, aerated water.

- Semi-trailer with Body. It is used in general purposes. Body side will protect the goods leave out during transferring.

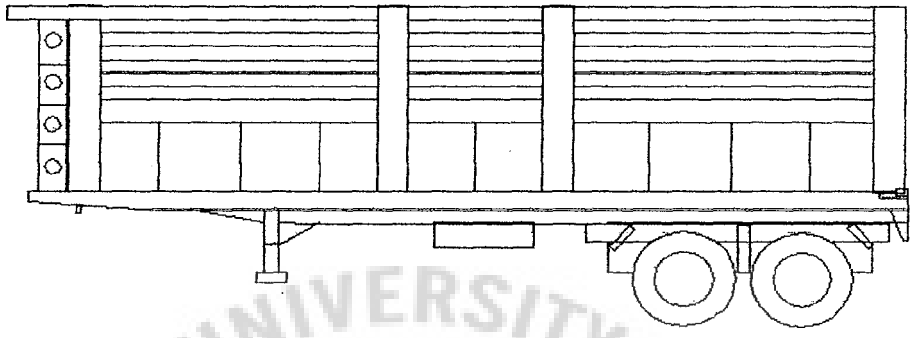


Figure 4.6. Semi-trailer with Body

Example of goods:

- Stone, soil and sand,
- Some agricultural goods: rice, cassava, corn, bean, fiber crops.
- Wood fuel: charcoal, firewood, saw dust, filings.
- Mine: coal, lignite, iron mine, silver ore, tin ore.
- Animal: buffalo, cow, pig, duck, chicken.

- Low Bed Flat Deck Semi-trailer. It is used for containing high object goods and high weight goods. The structure of this semi-trailer is made from high strength material. The maximum size of object is more than 3.5 meters.

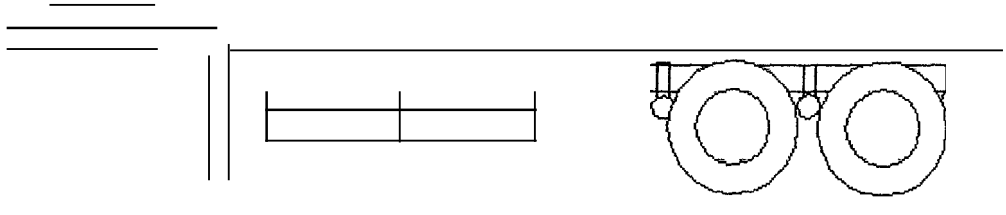


Figure 4.7. Low Bed Flat Deck Semi-trailer

Example of goods:

- Machine.
- Tractor.
- Excavator.
- Scraper.

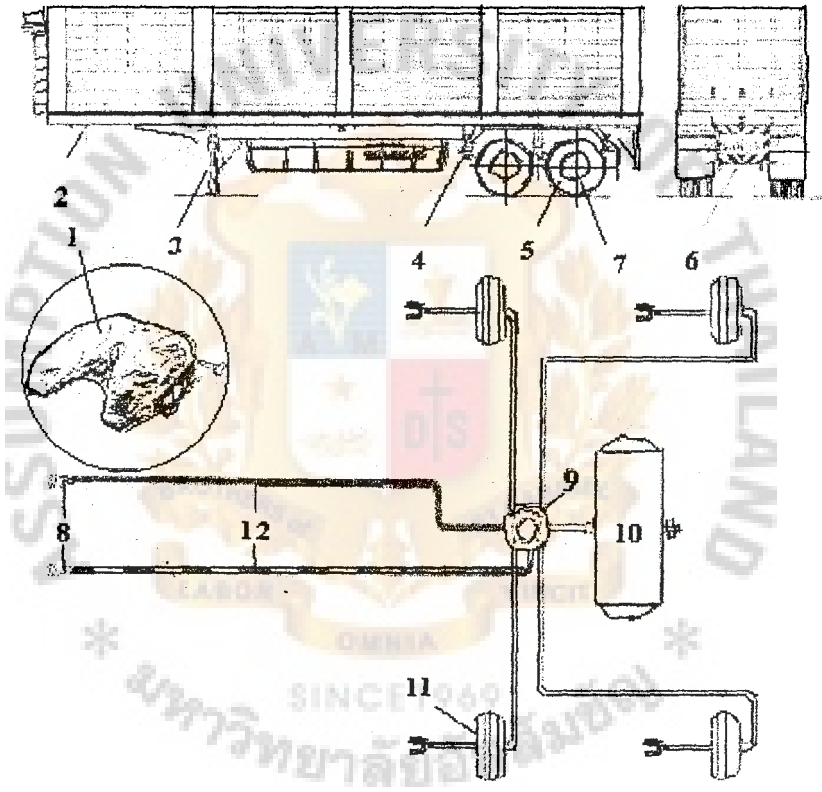


Figure 4.8. Main Equipment of Semi-trailer

- The notations for Figure 4.8.

Number	Name
1	The fifth wheel
2	King pin
3	Landing gear

4	Suspension system
5	Wheel and tire
6	Axle
7	Kilometer gauge
8	Jumper hose
9	Relay emergency valve
10	Air tank 50 liters
11	Brake booster
12	Nylon air pipe

- The Fifth (Coupler). Coupling device mounted on the semi-trailer tractor is coupling king pin of the trailer, The fifth wheel is divided into two classes according to their functions, single-axle and two-axle the.fifth wheel.

  - Single-axle the fifth wheel. Single-axle the fifth wheel is provided only with the pitching shaft and functions in accordance with tractor and trailer movement. In this case rolling movements are absorbed by the rear suspension spring on the tractor. Load supported by the fifth wheel is called the fifth wheel load.

  — Two-axle the fifth wheel, Two-axle the fifth wheel is comprises the pitching shaft and rolling shaft. By operating these shafts, relative pitching and rolling movements between the tractor and the trailer are absorbed.

- King Pin_ Coupling device attached to the semi-trailer and coupled to the tractor the fifth wheel so that the trailer can be hauled. The dimensions of the king pin vary according to load, that is, 2" or 3.5" diameter king pin can be selected.

- Jumper Cable. Electric wiring of the tractor and the trailer is performed by jumper cables and couplings. A plug at the end of the cable is to be inserted into the

socket of the trailer. Coupling system is based on the SAE (Society of Automobile Engineers) standards.

- Jumper Hose. Brake piping is performed by jumper hose and coupling. Jumper hoses comprise a pair of the hoses for service brake and emergency brake. A coupling is attached to the end of jumper hose. Coupling system is based on the SAE standards.

- Landing Gear. Landing gear is a stand for supporting trailer so that it may not tilt when separated from the tractor.

- Relay Emergence Valve. Relay emergency valve functions normally like relay valve. Should the trailer be separated from the tractor while running the valve operates the emergency brake to stand the trailer.

- Equipment of Semi-trailer's brake system.
  - Pneumatic coupling.
  - Relay emergency valve.
  - Air tank (50 liters).
  - Brake Booster.
  - Nylon-air pipe.

E, <u>Load and Size Specification</u>

From regulation of Ministry of Communication by Department of Transportation and Department of State Highways. The Law of Ministry of Communication vol.11, 1981 the load and size limit of semi-trailer will be assigned as follows:

- The load of tractor & semi-trailer.

Tractor

Type of axles	The weight of truck (include load: Tons)	The limited weight at rear axle (Tons)
1-1 Single tire	8.50	6.80
1-1 Double tires	12.00	9.10
1-2 Single tire	15.30	12.20
1-2 Double tires	21.00	16.40

* The first number means the number of front axles.

The second number means the number of rear axles.

The third words means the number of tires for rear axles.

Semi-trailer

Type of axles	The limited weight at rear axle (Tons)
Single axle-Single tire	6.80
Single axle-Double tires	9.10
Two axles-Single tire	12.20
Two axles-Double tires	16.40

- The maximum gross weight of Tractor & semi-trailer. The gross weight of semi-trailer depends on number of axles, axles spacing, and overall length. Some cases depend on number of tires and friendly suspension.

Axle spacing is the distance from rear axle of tractor to rear axle of semi-trailer. The point that uses to be reference point is the touching point of tire with road surface.

Two-axied tractive unit

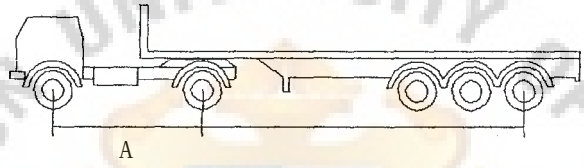


Figure 4.9. Two-axled Tractive Unit

Distance A (meters)	Gross weight of tractor (Tons)	Distance B (meters)	Gross weight of semi-trailer (Tons)
2.0≤A	14.23	2.0 B	20.33
2.45A	16.26	2.25B	22.36
2.7 ._. A	17.00	2.6 .-. B	23.37
		2.9 _-_ B	24.39
		3.2 ._.B	25.41
		3.5 _..B	26.42
		3.8 5 B	27.44
		4.1 5B	28.45
		4.4 ._ B	29.47
		4.7 <B	30.49
		5.0 B	31.50
		5.35B	32.52
		5.5<B	33.00+
		5.8 -. B	34.00}
		6.2 B	35.00k
		6.5 . B	36.00+
		6.7 < B	37.00+
		6.9 B	38.00+

Note:

1. Gross weight is more than 26.00 tons to be used with two axles semi-trailer or more than.

2. Gross weight is more than 35.00 tons to be used with three axles semi-trailer or more than.

3. Gross weight is more than 25.00 tons for single axle semi-trailer and gross weight is more than 32.52 tons for two axles semi-trailer are assigned :

   a. All driving axles are not steering driving axle must use double tires.

   b. All driving axles must use with friendly suspension.

Three- wded tractive unit

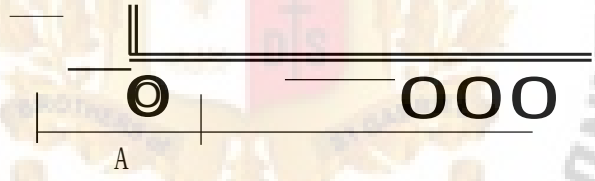


Figure 4.10. Three-axled Tractive Unit

Note:

Gross weight is more than 35.00 tons for two axles semi-trailer,

- For.four axles series are as follows:

   a. International tractor & semi-trailer.

   b. All driving axles are not steering driving axle must use double tires.

   c. All driving axles must use friendly suspension.

For gross weight is more than 38_00 tons with three axles semi-trailer are as follows:

   a. Co-operate with train.

   b. All driving axles are not steering driving axle must use double tires.

c. All driving axles must use friendly suspension.

- MIAW = Minimum Average Weight

Distance A (meters)	Gross weight of tractor (Tons)	Distance B (meters)	Gross weight of Semi-trailer (Tons)
3.0 _<_ A	20.33 (MIAW 8.39)	2.0 B	20.33
		2.2 _-. B	22.36
3.8 < A	22.36 (MIAW 8.64)	2.6 B	23.37
		2.9 _<_ B	24.39
4.0 <A	22.50 (MIAW 10.50)	3.2 <B	25.41
		3.5 -_ B	26.42
4.3 A	24.39 (MIAW 9.15)	3.8 _ B	27.44
		4.1 -_ B	28.45
4.8<A	24.39 (MIAW 10.50)	4.4< B	29.47
		4.7 -.B	30.49
		5.0 <B	31.50
		5.3 __ B	32.52
		5.4 ._. B	33.00+
		5.6 . 13	34.00+
		5.8 ._. B	35.00+
		6.0 <B	36.00
		6.2 < B	37.00
		6.3 . B	38.00
		6.7 B	39.00+
		7.1 _<_ B	40.00+
		7.4<B	41.00+
		7.6 _ B	42.00+
		7.8 <B	43.00+
		8.0 . 13	44.00+

- Overall length.

From Standard of EU Directive 85/3, 1973 assign the overall length of tractor & semi-trailer as follows:

The Overall Length of Tractor and. Semi-trailer

Type	Overall Length (meters)
Tractor and Semi-trailer	16.5*
Tractor and Semi-trailer with Low Loader	18
Tractor and Semi-trailer for Car Transporter - From king pin to rear - From king pin to front	 12.5 4.19
Other type - From king pin to rear - From king pin to front	 12' 2.04+

* Maximum length is non-limit for non-assembly object goods.

+ This length is include the thick of wall. In case: to have a lot of king pin, this length is measured from the last king pin.

- Turning circle-articulated vehicles.

In case, the overall length of tractor & semi-trailer is more than 15.5 m. It must can turn in the co-circle with radius 12.5 m. and 5.3 m.

Some types will be excluded for this law. They are as follows:

- Tractor & semi-trailer that its overall length is no more than 15.5 m.
- Tractor & semi-trailer with low loader.
- Tractor & semi-trailer that use for carrying non-assembly goods.
- Tractor & semi-trailer with stepframe low loader.

F. Distribution Force

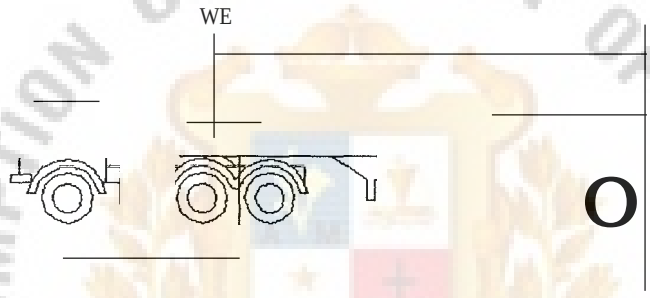


Figure 4.11. Distribution Force of Tractor & Semi-trailer

W1, W2, W3	=	Axle load (kilogram, kg.)
Wa	=	The fifth wheel load (kilogram, kg.)
Wb	=	Payload (kilogram, kg.)
L1	=	Tractor wheel base (meter, m.)
L2	=	Semi-trailer wheel base (meter, m.)
X	=	King Pin offset (meter, m.)
W1l'W2iLW3	=	Gross combination weight (kilogram, kg.)

Formulas in calculating the load of tractor and semi-trailer:

W2L1 + W3 (Li+ L2 — X) - Wa(L1 Wb(Li+ L2— X —Y)

WiLl Wb Y - X) - $W_3(L_2 - X) + W_aX$

$W_1(L_1 + L_2 — X) + W2 (L2 — X) = WaL2\ WbY$

$W1+W2^{-1-}W3 = Wa\ Wb$

G. Trend of Tractor and Semi-Trailer Requirements (nalillfilltlanlITILLC414, 2529)

Demand of tractor and semi-trailer is higher every year. Because it is the efficiency alternative in using such as: increase quantity of goods per trip, reduce cost, economize in investment, etc. Trend of increasing in tractor and semi-trailer requirement is important to study for improvement in the transportation system of Thailand.

In forecasting tractor and semi-trailer requirement, the past data of its requirement is necessary to use in forecasting the requirement in the future. The technique is advised to be the linear regression technique. The past data are obtained from Ministry of Transportation and Communication in year 1984 to 1996.

Table 4.1. The Past Data of Semi-trailer Demand in year 1983 - 1996

Year	Value of goods in Thailand (transfer with tractor and semi-trailer) (Billion baht)	Semi-trailer requirement (Cars)
1984	380.74	2,029
1985	394.11	2,312
1986	413.49	2,549
1987	452.63	2,735
1988	512.47	2,898
1989	574.20	4,645
1990	631.60	6,776
1991	682.13	7,980
1992	738.06	8,398
1993	798.59	9,543
1994	864.07	10,782
1995	934.93	12,123
1996	1011.59	13,574

The linear regression formula:

$$Y = a + bX$$

given:

The quantity of semi-trailer (Cars)

$X =$ Value of goods in Thailand (Billion baht)

$a =$ Constant

Constant

$$b = \frac{nEXY - EXZY}{nEX^2 - (X)^2}$$

$$a = ZY - bEX$$

Correlation Coefficient (r) and Coefficient of Determination (r^2)

$$r = \frac{nIXY - IXEY}{V[nEx^2 - (Ex)^2 1[nE\ y^2 - (Y)^2]}$$

Year	Value of goods in Thailand (transfer with tractor and semi-trailer) (Billion baht) X	Semi-trailer requirement (Cars) Y	X^2	XY
1984	380.74	2,029	144,962.95	772,521.46
1985	394.11	2,312	155,322.69	911,182.32
1986	413.49	2,549	170,973.98	1,053,986.01
1987	452.63	2,735	204,873.92	1,237,943.05
1988	512.47	2,898	262,625.50	1,485,138.06
1989	574.20	4,645	329,705.64	2,667,159.00
1990	631.60	6,776	398,918.56	4,279,721.60
1991	682,13	7,980	465,301.58	5,443,397,40
1992	738.06	8,398	544,732.56	6,198,227.88
1993	798.59	9,543	637,745.99	7,620,944.37
1994	864.07	10,782	746,616.96	9,316,402.74
1995	934.93	12,123	874,094.10	11,334,156.39
1996	1011.59	13,574	1,023,314.33	13,731,322.66
Total	8,388.61	86,344	6,959,188.52	66,052,102.94

$$b = \frac{nEXY - EXEY}{flE\ x^2\ (Ex)^2}$$, n = 13

18.923

$$a = EY - bX$$

a -5,596.21

$$r = \frac{nEXY - EXEY}{i[nE\ X^2 - (E\ X)^2][nE\ Y^2 - (E\ Y)^2 I}$$

0.9924

r^2 0.9849 ; nearly 1, So the data are accept.

$$Y = -5{,}596.21 + 18.923X$$

The expect of quantity of semi-trailer in year 1997 to 2008 can be calculated as follows:

Year	Value of goods in Thailand (transfer with tractor and semi-trailer) (Billion baht) X increase 8.2 % per year	Semi-trailer requirement (Cars) y = -5,596.21 + 18.923X
1997	1,094.54	15,143
1998	1,184.29	16,842
1999	1,281.40	18,679
2000	1,386.44	20,667
2001	1,500.13	22,819
2002	1,623.14	25,147
2003	1,756.24	27,665
2004	1,900.25	30,391
2005	2,056.07	33,309
2006	2,224.67	36,530
2007	2,407.09	39,982
2008	2,604.47	43,717

H. Operating Cost (Trader's view)

Operating cost is divided into two parts: Running costs and Standing costs. Details of each part can discussed as follows:

Running costs consist of

- Fuel consumption.
- Lubricating oil consumption.
- Vehicle maintenance parts consumption.
- Vehicle maintenance labor hours.
- Tire consumption.
- Vehicle depreciation.
- Crew hours.

Standing costs is about 25% of Running costs.

I. Factors in Considering Operation Cost

- Rise and Fall of road (RS,F).
- Vehicle speed (V).
- Power to weight ratio (PW).
- Gross Vehicle Weight (GVW).
- Roughness of road (R).
- Cumulative kilometres (K).
- Average annual kilometres (KA).
- Vehicle age in years or Life Time.
- Vehicle price (VP).

V. A CASH FLOW ANALYSIS

The operating costs of truck and tractor & semi-trailer are discussed in many chapters early. In the trader's view, those costs are important for survival of business. Traders must concentrate in those costs to analyze and find the optimum point of them.

In this chapter, many methods, that used to analyze the operating costs, will be introduced to be guide for analyzing the cash flow of the operating costs.

The symbols and terms of equation of standard notation that used in this chapter are shown as follows:

Table 5.1. Financial Symbols in Cash Flow Analysis

Factor name	Standard notation
Single-payment present-worth (SPPWF)	(P/F,i%,n)
Single-payment compound-amount (SPCAF)	(F/P,i%,n)
Uniform-series present-worth (USPWF)	(P/A,i%,n)
Capital-recovery (CRF)	(A/P,i%,n)
Sinking-fund (SFF)	(A/F,i%,n)
Uniform-series compound-amount (USCAF)	(F/A,i%,n)

Table 5.2. Financial Symbols and Their Formula

To find	Given	Factor	Equation	Formula
P	F	(P/F,i%,n)	P = F(P/F,i%,n)	$P = F[\frac{1}{(1+i)^n}]$
F	P	(F/P,i%,n)	F = P(F/P,i%,n)	$F = P(1+i)^n$
P	A	(P/A,i%,n)	P = A(P/A,i%,n)	$P = A[\frac{(1+i)^n-1}{i(1+i)^n}]$
A	P	(A/P,i%,n)	A = P(AJP,i%,n)	$A = P[\frac{i(1+i)^n}{(1+i)^n-1}]$
A	F	(A/F,i%,n)	A = F(A/F,i%,n)	$A = F[\frac{i}{(1+i)^n-1}]$
F	A	(F/A,i%,n)	F = A(F/A,i%,n)	$F = A[\frac{(1+i)^n-1}{i}]$

P = Present value

F = Future value

A = Equivalent uniform animal series

Interest rate, % per period

n = The number of periods

There are different methods that will be introduced as follows:

A. Payback Period (PB) (Brigham,1997)

The payback period is the expected number of years required to recover the original investment. For the investment in truck or tractor & semi-trailer, the steps in analyzing the operating costs of them are:

i. Set the operating costs into the cash flow form includes the revenue in each year.

ii. Analyze the cash flow to calculate the payback period.

iii. Compare the result between truck and tractor & semi-trailer.

iv. Select the best alternative; use results from this method to be criteria.

The example for this method will be shown as follows:

- Investment 1.

The initial cost = I

The total operating costs per year = OP_i

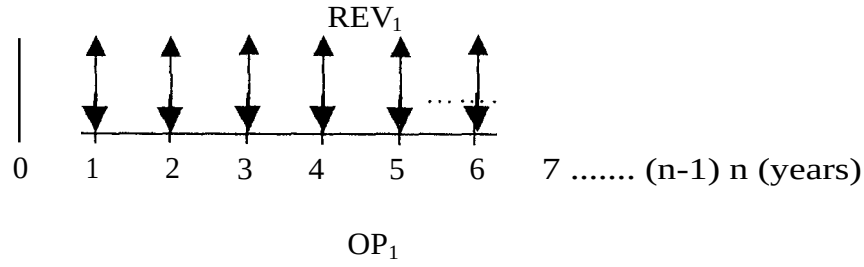
The revenues per year = REV_1

The life time of truck

The salvage value = SV_1

The cost of capital = i% per year

Its cash flow will be set in Figure 5.1:



The cost of capital = i % per year

The cost of capital = i % per year

Figure 5.1: Cash Flow of Investment 1 (PB)

Calculate payback period;

	0	1	2	3	4	5	6	7 ..... (n-1)	n (years)
Net cash flow		X	X	X	X	X	X	X X	$(X+SV_1)$
Cumulative		Y_i	Y2	Y3	Y4	Y5	Y6	Y7 - • - - • • Y(n-1)	Yn

$X = (REV_1 - OP_1)$

$Y_1 = (-I1 + X)$

$Y2 = (Yi \pm X)$

$Y3 = (Y2 + X)$

$Y_4 = (Y3 +$

$Y(n-1) \quad (Y(1-2) + X)$

$Yn = (Y(n-1) + X +$

Considering at Value Y, whatever year that gives the first plus number of Y, the payback period will be between the year before that year and that year.

Assume that, the 6th year give the first plus number of Y, then:

$$PB_1 = 5 + Y_5 / X$$

- Investment 2.

The initial cost

The total operating costs per year = OP_2

The revenues per year = REV_2

The life time of truck n

The salvage value = SV_2

The cost of capital i% per year

Its cash flow will be set in Figure 5.2 :

S V2

REV2

0 1 2 3 4 5 6 7 ... (n-1) n (years)

OP_2

The cost of capital = i % per year

SV_2

$(REV_2 - 0P2)$

0 3 4 5 . 7 0-1 n (years)

The cost of capital = i % per year

Figure 5.2. Cash Flow of Investment 2 (PB)

Calculate payback period;

	0	1	2	3	4	5	6	7	. (n-1)	n (years)
Net cash flow 42		X	X	X	X	X	X	X.,, ...	X	(X+SV2)
Cumulative		Y_1	Y2	Y3	Y4	Y5	Y6	Y7 -	---Y(n- I)	Yn

$X = (REV2 — 0P2)$

$Yi = (C^{4}2 + X)$

$Y2 = (Y1 + X)$

$Y3 = (Y2 + X)$

$Y4 = (Y3 + X)$

$Y(n-1) \quad (Y(n-2)^{+} X)$

$Yn = (Y(n-1) X + SV2)$

Considering at Value Y, whatever year that gives the first plus number of Y, the payback period will be between the year before that year and that year.

Assume that, the 8th year give the first plus number of Y, then:

$PB_2 \quad 7+ \quad I X$

The result shows that $PB_1 < PB_2$

So, The investment 1 should be invested more than investment 2.

B. Discount Payback Period (DPB) (Brigham,1997)

The discount payback period is defined as the number of years required recovering the investment from discounted net cash flows. For the investment in truck or tractor & semi-trailer, the steps in analyzing the operating costs of them are:

i. Set the operating costs into the cash flow form includes the revenue in each year.

ii. Discount net cash flow in each year into value in year 0.

iii. Analyze the cash flow to calculate the discounted payback period.

iv. Compare the result between truck and tractor & semi-trailer.

v. Select the best alternative; use results from this method to be criteria.

The example for this method will be shown as follows:

- investment 1.

The initial cost

The total operating costs per year = OT_1

The revenues per year = REV_1

The life time of truck

The salvage value = SV_1

The cost of capital = i% per year

Its cash flow will be set in Figure 5,3

SV_I

REV_1

0 1 2 3 4 5 6 7 .... . (n-1) n (years)

OP_i

The cost of capital = i % per year

SV_1

$(REV_i\ OP1)$

0 2 3 4 5 6 (n-1) n (years)

The cost of capital = i % per year

Figure 5.3. Cash Flow of Investment 1 (DPB)

Calculate discounted payback period;

0 1 2 3 4 5 6 7 ..... (n-1) n (years)

Net cash flow X X X X X X X ..... X $(X+SV_1)$

Discounted NCF $-I_I$ Z_1 Z_2 Z_3 Z_4 Z_5 Z_6 Z_7 ... $Z_{(n-1)}$ Q_n

Cumulative Y1 Y2 Y3 Y4 Y5 Y6 Y7 - • • • • • Y(n-1) Yn

$$X = (REV_i - OP_1)$$

$$Z_i = X/(1+O^1$$

Z_2 = Xi(1 +0^2

Z3 V(1 +1)^3

Z4 = Xi(1 +0^4

Z5 = Xi(1+1)^5

4.-4) m1+0$^{(-1)}$

Q. = (x+svoio+on

Y_1 = (41+ z1)

Y2

Y3 – (Y$_3$+++ Z$_4$))

Y4

Y(n-1) (Y(n-2) Z(n-1))

Yn – (Y(.4)+ Q)

Considering at Value Y, whatever year that gives the first plus number of Y, the discounted payback period will be between the year before that year and that year.

Assume that, the 6th year give the first plus number of Y, then:

$$DPB_1 = 5 + 5/.6$$

- Investment 2.

The initial cost I2

The total operating costs per year = OP_2

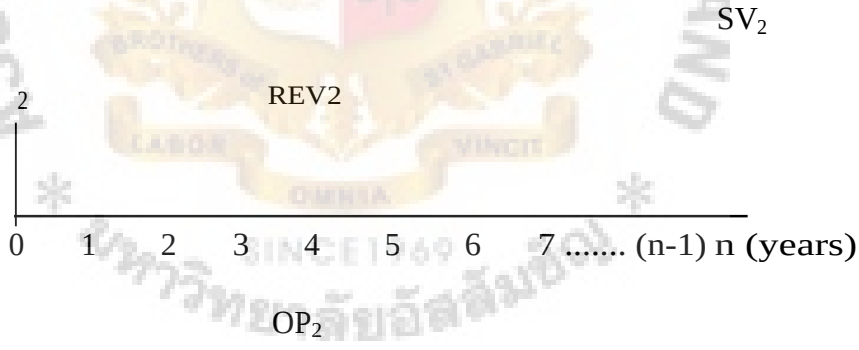
The revenues per year = REV_2

The life time of truck

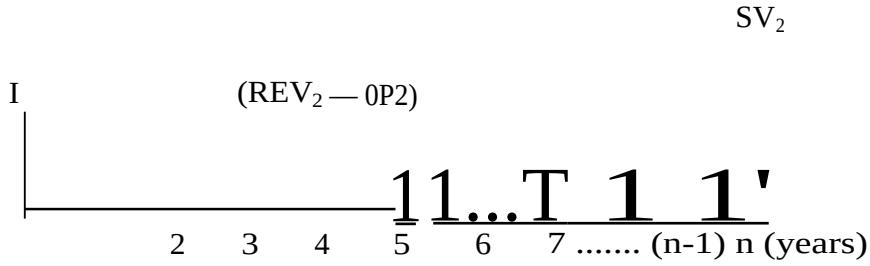
The salvage value = SV2

The cost of capital = i% per year

Its cash flow will be set in Figure 5.4 :



The cost of capital = I % per year



The cost of capital = I % per year

Figure 5.4. Cash Flow of Investment 2 (DPB)

Calculate discounted payback period;

	0	1	2	3	4	5	6	7 ..... (n-1)	n (years)
Net cash flow	-1_2	X	X	X	X	X	X	X X	(X+SV2)
Discounted NCF	-1_2	Z_1	Z_2	Z_3	Z_4	Z_5	Z_6	Z_7 ...	Z(n-1) Qn
Cumulative		Y_1	Y2	Y3	Y4	Y5	Y6	Y7 - •--•--	Y(rp-1) Yn

(REV2 - 0P2)

$X/(1+1)^1$

Z_2 = x/(1-1-0^2

7_4 = xio+0^4

z_5 x/(1+0^5

Z-1) = x/(1+0(n^{-1})

Qn =

Yi = (4_1 + Z_1)

Y2 (Yi + Z_2)

Y3 = (Y2 + Z3)

Y4 (Y3 + Z4)

Y(n-1) (Y(n-2) Z(n-1))

Yn = (Y(n-I)+ Q)

Considering at Value Y, whatever year that gives the first plus number of Y, the discounted payback period will be between the year before that year and that year.

Assume that, the 8th year give the first plus number of Y, then:

$$DPB_2 = 7 + Y_7 / Z_8$$

The result shows that $DPB_1 < DPB_2$

So, The investment 1 should be invested more than investment 2.

C. Internal Rate of Return (IRR) (Blank, 1989)

The IRR is defined as that discount rate which equates the present value of a project's expected cash inflows to the present value of the project's expected costs or, equivalently, forces the Equivalent-Uniform-Annual-Worth (EUAW) or Net-Present-Worth (NPW) to equal zero.

$$NPV = \sum_{f=0} \frac{CF}{(1+i)^{f}} = 0$$

The IRR of each alternative or project cannot be compared directly because initial cost of each alternative is not the same. The method that can apply IRR to compare alternatives to select the best among a lot of alternatives is the Incremental-Rate-of-Return.

The Incremental-Rate-of-Return steps.

Order the alternatives in terms of increasing initial investment cost.

ii. For alternatives which have positive cash flows, consider the "do-nothing" (i.e., zero cash flow) alternative as a defender and compute the incremental rate on return IRR between the do-nothing alternative and the alternative requiring the lowest initial investment. For alternatives having only costs, skip to step 4, using the lowest initial investment cost alternative as the defender and the next-higher one as the challenger.

iii. If IRR< i, remove the lowest-investment alternative from further consideration and compute the overall rate of return for the next-higher-investment

alternative. Repeat this step until IRR i for one of the alternatives. When IRR i , that alternative becomes the defender and the next higher-investment alternative is the challenger.

iv. Determine the net (incremental) cash flow between the challenger and defender.

v. Calculate the rate of return on the incremental investment required by the challenger using the net cash flow.

vi. If the rate of return calculated in step 5 is greater than the i, the challenger becomes the defender and the previous defender is removed from further consideration. Conversely, if the rate of return in step 5 is less than the i, the challenger is removed from further consideration and the defender remains as the defender against the next challenger.

vii. Repeat steps 4 to 6 until only one alternative remains.

The example of IRR method for one alternative will be shown as follows:

- Investment 1.

The initial cost

The total operating costs per year = $()P_i$

The revenues per year = REV_1

The life time of truck n

The salvage value = $SA/_1$

The cost of capital % per year

Its cash flow will be set in Figure 5.5:

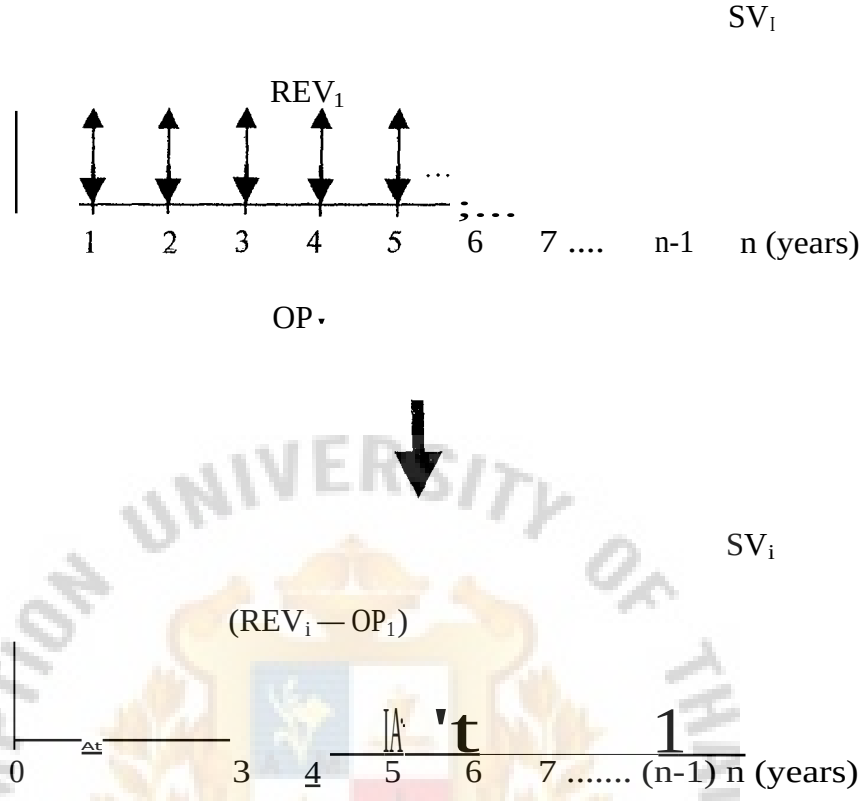


Figure 5.5. Cash Flow of Investment 1 (IRR)

$$X = (REVI\text{-}OP1)$$

$$NPV_i = (REV_i - OP_I + SV_I) + X/(1+IRR_I)^1 + X/(1+IRR_1)^2 + X/(1+IRR_I)^3 + \\ + X/(1+1RR_i)^{(11-1)} + Y/(1+IRR_1)^{\circ} \\ 0$$

If $IRR_I > i$ then this alternative is accepted.

If $IRR_I < i$ then this alternative is rejected.

The example of the Incremental-Rate-of-Return method for two alternatives will be shown as follows:

- Investment 1.

Initial cost	=	I_i
Operating cost	=	OP_i (per year)
Revenue	=	REV_I (per year)
Salvage value	=	SV_1
Life time	=	n_1 years

- Investment 2.

Initial cost	=	1_2
Operating cost	=	OP_2 (per year)
Revenue	=	REV_2 (per year)
Salvage value	=	SV_2
Life time	=	n_2 years

The cost of capital for both investment is i % per year.

If $1_2 > I_I$ and apply IRR on EUAW base.

Assume comparing with do nothing $UR_I > i$ then investment 1 is selected.

Next, compare investment 1 and 2 on EUAW base.

EUAW2-i 4_2(A/PORR$_{24}$,n_2) — OP_2 + REV_2 +SV2(A/F,IRR2_1,n2) —

(-I1(A/P,MR2-bn1) — $01^3$1 + REV_I +SV1(A/F,1R2-2-1,n1)

- 0

Calculate $IRR_{2\cdot 1}$ for this equation_

If IRR_{24} i then the investment 2 is selected and investment I is rejected.

If $IRR_{2\text{-}1}$ < i then the investment 1 is selected and investment 2 is rejected.

D. Net Present Value (NPV) (Brigham,1997)

Net Present Value (NPV) is the one method that used to select best alternative among many alternatives. It is a discounted cash flow methodology. Its steps are as follows:

i. Find the present value of each period's net cash flow, including both inflows and outflows, discounted at the project's cost of capital.

ii. Sum these discounted net cash flows; this sum is defined as the project's NPV.

iii. If the NPV is positive, the project should be accepted. If the NPV is negative, it should be rejected. And if two projects are mutually exclusive, the one with the higher positive NPV should be chosen.

$$NPV \quad \frac{CF_t}{(1+i)^t}$$

CF_t = Cash Flow at time t

The example of NPV method for one alternative will be shown as follows:

- Investment I.

The initial cost

The total operating costs per year = $°P_i$

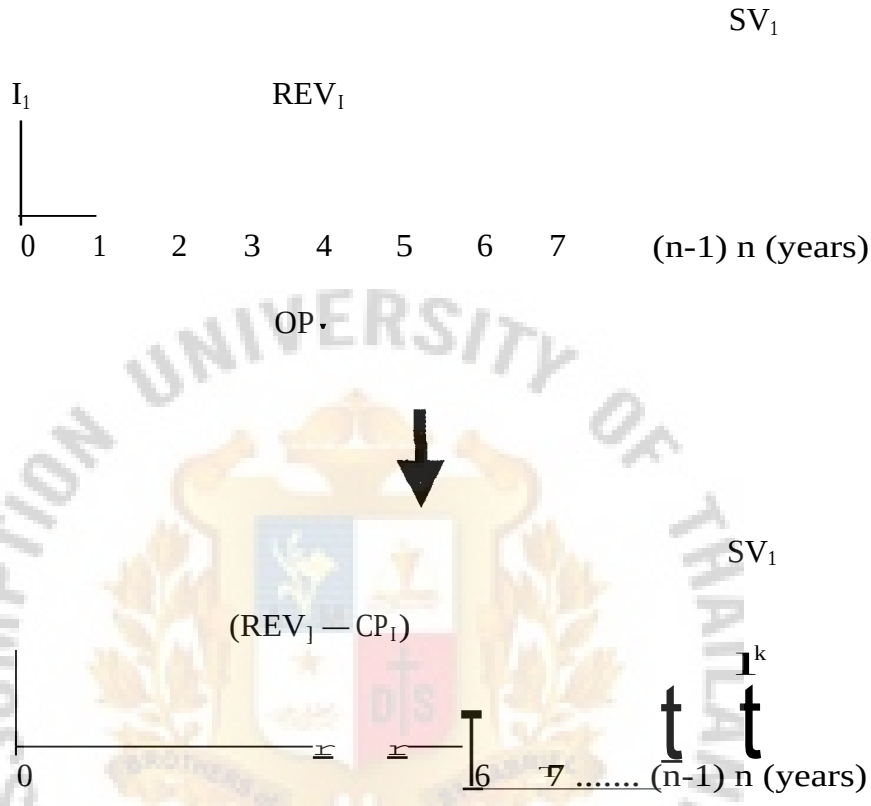
The revenues per year = REV_1

The life time of truck n

The salvage value = SV_1

The cost of capital i % per year

Its cash flow will be set in Figure 5.6:



Cost of capital = i% per year

Figure 5.6. Cash Flow of Investment 1 (NPV)

$X = (REV_I - OP_1)$

$(REV_I - OP_I + SV_i)$

$NPV_1 = \quad + X/(1+i)^1 + X/(1+0^2 + X/(1+i)^3 +$

$+ X/(14\text{-}0^{(n-1)}\ Y/(1+i)^n$

- Investment 2.

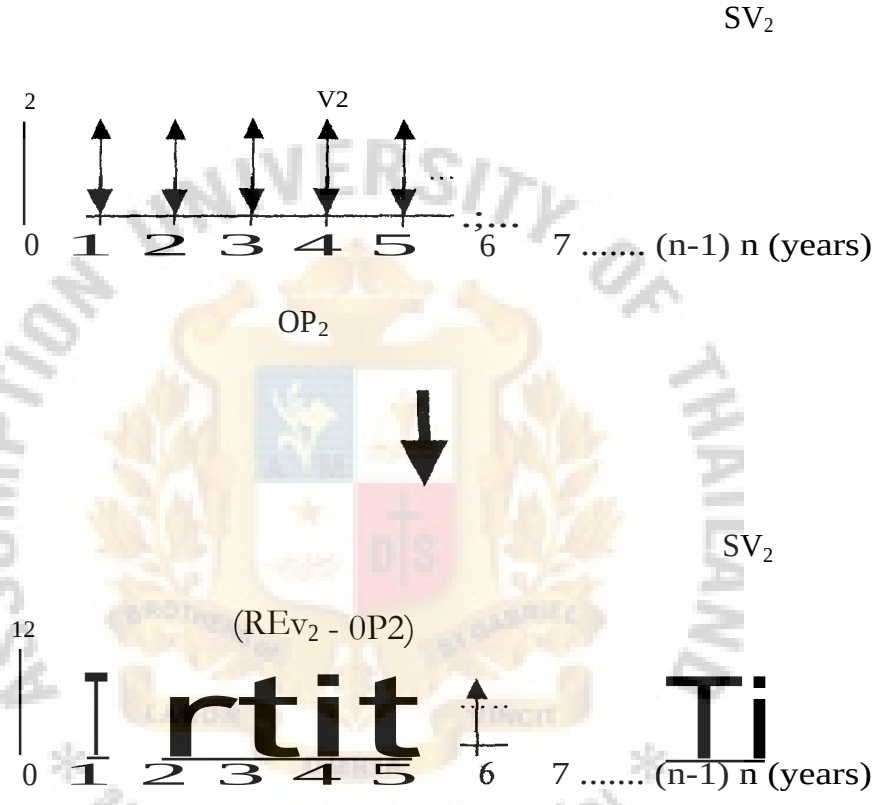
The initial cost

The total operating costs per year = OP2

The revenues per year = REV_2

The life time of truck		n
The salvage value	=	SV_2
The cost of capital		i % per year

Its cash flow will be set in Figure 5.7:



The cost of capital = i % per year

Figure 5.7. Cash Flow of Investment 2 (NPV)

$$X = (REV2\text{-}0P2)$$

$$Y = (REV_2\text{-}OP_2+SV_2)$$

$$NPV_2 - \quad -I_2 + X/(1+i)^1 + X/(1+i)^2 + X/(1+1)^3 +$$

$$+ X/(1+i)^{(n-1)} +$$

If $NPV_1 > NPV_2$ then alternative 1 is accepted and alternative 2 is rejected.

If $NPV_1 < NPV_2$ then alternative 1 is rejected and alternative 2 is accepted.

E Equivalent Uniform Annual. Worth (EUAW) (Brigham,1997)

Equivalent Uniform Annual Worth (EUAW) is the one method that used to select best alternative among many alternatives. Its steps are as follows:

i. Find the annually value of each period's net cash flow, including both inflows and outflows.

ii. Sum these annually net cash flows; this sum is defined as the project's EUAW.

iii. If the EUAW is positive, the project should be accepted. If the EUAW is negative, it should be rejected. And if two projects are mutually exclusive, the one with the higher positive EUAW should be chosen.

$$EUAW \underset{t=0}{E} CF,(A\ I\ P\ ",t)$$

The example of EUAW method for one alternative will be shown as follows:

- Investment 1.

The initial cost

The total operating costs per year = OP_1

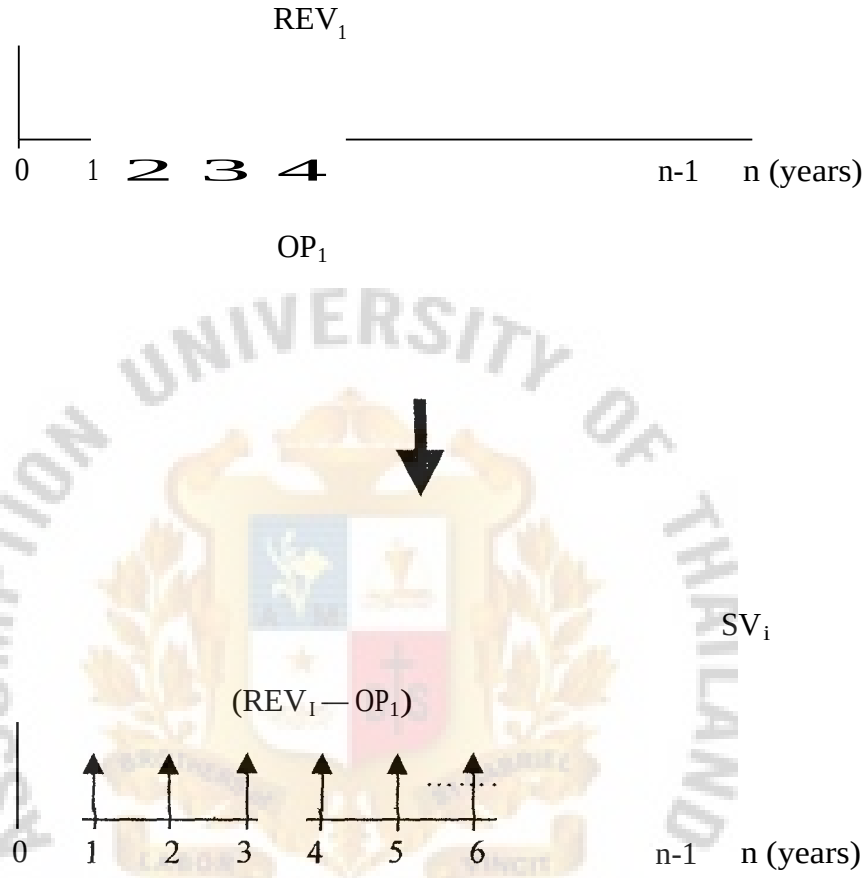
The revenues per year = REV_i

The life time of truck n

The salvage value SV_1

The cost of capital % per year

Its cash flow will be set in Figure 5.8:



Cost of capital = i% per year

Figure 5.8. Cash Flow of Investment 1 (EUAW)

$$X = (REV1-OP1)$$

$$EUAW_1 = -I_i(A/P,i\%,n) + X + SV_I(A/F,i\%,n)$$

- Investment 2.

The initial cost = $_{-2}$

The total operating costs per year = OP_2

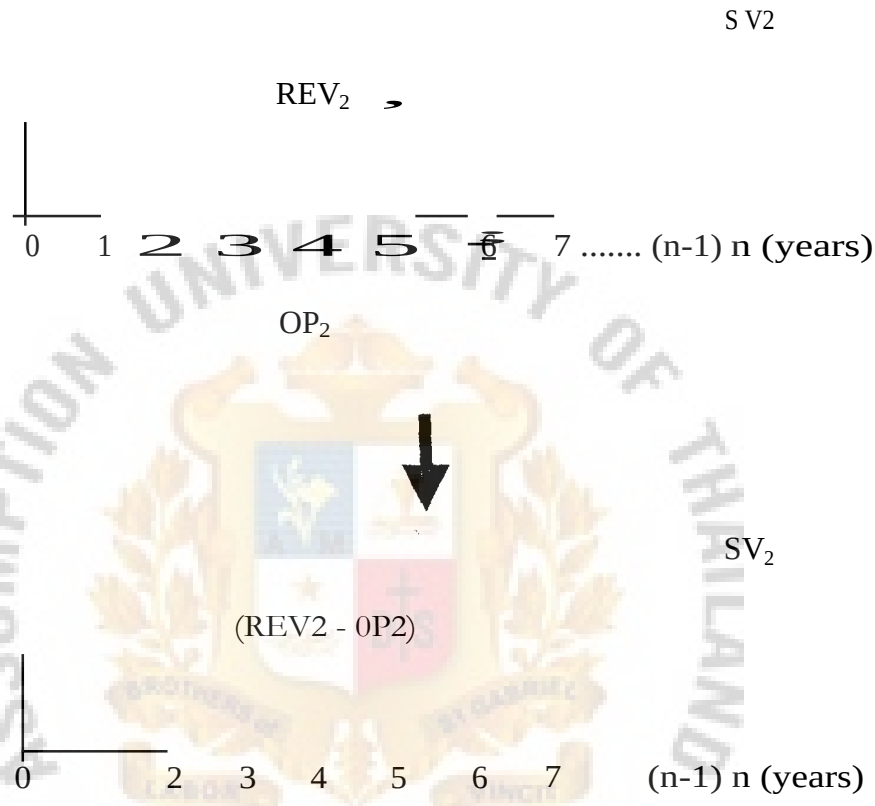
The revenues per year = REV_2

The life time of truck

The salvage value S V2

The cost of capital i % per year

Its cash flow will be set in Figure 5.9:



The cost of capital = i % per year

Figure 5.9. Cash Flow of Investment 2 (EUAW)

$$X = (REV_1 - OP_1)$$

$$EUAW_2 = 4_2(A/P,i\%,n) + X + SV_2(AIF,i\%,n)$$

If EUAW > $EUAW_2$ then alternative 1 is accepted and alternative 2 is rejected.

If $EUAW_1$ < $EUAW_2$ then alternative 2 is accepted and alternative 1 is rejected.

F. Profitability Index (PI) (Brigham,' 997)

One method that used to evaluate a lot of alternatives is the profitability index (PI). This method will divide terms of costs and revenues into two groups, cash inflows or benefits and cash out flows or costs. The PI shows the relative profitability of any alternative, or the present value of benefits per present value of costs.

The PI method of analysis is based on the ratio of the benefits to costs associated with a particular alternative. A alternative is considered to be attractive when the benefits derived from its implementation exceed its associated costs.

$$\text{Conventional PI} = \frac{\text{benefits disbenejits}}{\text{costs}} \quad \frac{B - D}{}$$

This formula is proper with the alternative that is not machine selection or widely alternative. It is a general formula.

$$\text{Modified PI} = \frac{\text{benefits} - \text{disbenefits} - \text{O\& M Costs}}{\text{initial investment}} \quad \frac{B - D - \text{O\& M}}{}$$

This formula is proper with the alternative that is machine selection.

An alternative is acceptable if its PI is greater than 1.

- Cash inflows or Benefits are advantages, expressed in terms of money, which happen to the owner.
- Cash outflows or Costs are the anticipated expenditures for construction, operation, maintenance, etc., less any salvage value.

The PI of each alternative or project cannot be compared directly because initial cost of each alternative is not same value. The method that can apply PI to compare alternatives to select the best among a lot of alternatives is the Incremental Profitability Index.

The Incremental Profitability Index steps.

i. Arrange the initial cost of every alternative from low to high.

ii. Divide the costs and revenues of each alternative into two groups, cash inflows and cash outflows.

iii. Compare alternatives with pair-wise method from low initial cost to high initial cost. The first pair is the first two lowest initial cost alternatives.

iv. Calculate the different number of monetary term of each pair (Cash inflows, Cash outflows) and set cash flow for them.

v. Calculate the PI of cash flow in step 4.

vi. If PI I then the higher initial cost alternative will be accepted.

If PI < 1 then the lower initial cost alternative will be accepted.

vii. Compare the selected alternative in step 6 with the next low alternative.

viii. Repeat step 4 to 6.

ix. Repeat step 7 to 8 until obtains the best alternative.

The example of PI method for one alternative will be shown as follows:

- Investment 1.

The initial cost

The total operating costs per year = OP_1

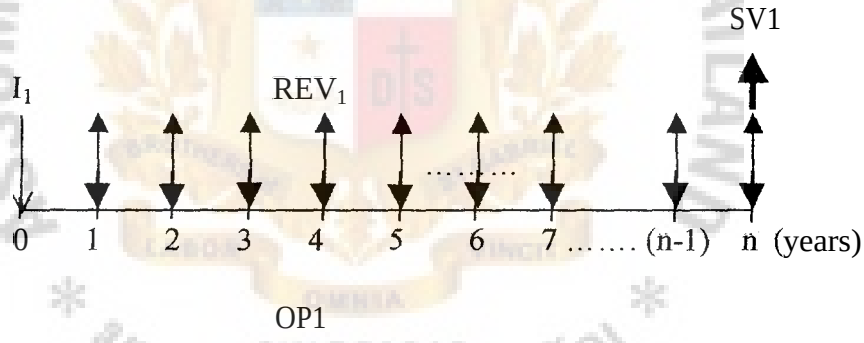
The revenues per year = REV_1

The life time of truck

The salvage value = SV_1

The cost of capital = i % per year

Its cash flow will be set in Figure 5.10:



The cost of capital = i % per year

Figure 5.10. Cash Flow of Investment 1 (PI)

This Alternative :Benefits or cash inflows is Revenue and Salvage value.

Costs or Cash outflow is Initial cost and Operating cost.

Cash inflows = $REV_1 + SVI(A/F,i\%,n)$

Cash outflows = $I_1(A/P,i\%,n) + OP_1$

Pl_i == Cash inflows / Cash. outflow

If PI_1 i then this alternative is accepted.

If PI• < i then this alternative is rejected.

The example of the Incremental Profitability Index method for two alternatives will be shown as follows:

- Investment 1.

Initial cost = I_1

Operating cost = OP_1 (per year)

Revenue = REV• (per year)

Salvage value = SV_1

Life time n_1 years

Alternative 1:Benefits or cash inflows is. Revenue and Salvage value.

Costs or Cash outflow is Initial cost and Operating cost.

- Investment 2.

Initial cost = I_2

Operating cost = OP_2 (per year)

Revenue = REV_2 (per year)

Salvage value = SV_2

Life time = n2 years

Alternative 2: Benefits or cash inflows is Revenue and Salvage value.

Costs or Cash outflow is Initial cost and Operating cost.

The cost of capital for both investment is i % per year.

If $1_2 > 1_1$ and apply PI on EUAW base.

Compare investment 1 and 2 on EUAW base.

Cash inflows = $\{REV_1 + SV1(A/F,i\%,111)\}+$

$\{REV_2 + SV2(A/F,i\%,n2)\}$

Cash outflows = $(I_1(A/P,i\%,n_1) + O_1 11 +$

$\{I2(A/P,i\%,n2)\ 0P_2\}$

PI_{2-1} = Cash inflows / Cash outflow

If PI_{2-1} 1 then the investment 2 is selected and investment 1 is rejected.

If $PI_{2-1} < 1$ then the investment 1 is selected and investment 2 is rejected.

G. Modified Internal Rate of Return (MIRR) (Brigham,1 997)

The modified IRR (MIRR) method corrects some of the problems with the regular IRR. MIRR. involves finding the terminal value (TV) of the cash inflows compounded at the firm's cost of capital and then determining the rate (MIRR) which forces the present value of the TV to equal the present value of the outflows. Still, conflicts can arise between MIRR and NPV if projects differ in size, and where conflicts arise, the decision should generally be based on the NPV.

Its equation is defined as follows:

PV costs = PV terminal value

$$\underline{COF;} \quad \frac{CIF\ (1+i)n^{-r}}{(1+IVIRR)^{n}}$$

$$PV\ costs — \frac{TV}{(1+ \text{ivfliRR})^{n}}$$

$$TV \quad {}^{Jt} \quad CIF,(1+$$

$$I.0$$

The equation looks complicated, but it really is not. COF refers to cash outflows, or the cost of the project, and CIF refers to cash inflows. The left term is simply the PV of the investment outlays when discounted at the cost of capital, and the numerator of the right term is the total future value of the inflows, assuming the inflows are reinvested at the cost of capital. The future value of the inflows is also called the terminal value, or TV. The discount rate that forces the PV of the TV to equal the PV of the costs is defined as the MIRR.

The modified IRR is superior to the regular IRR as an indicator of a alternative's "true" rate of return, or "expected long-term rate of return," but the NPV method is still better for choosing among competing alternatives because it always provides a good indicator of how much each alternative contributes to the value of the firm.

The example of MIRR method for one alternative will be shown as follows:

- Investment 1

The initial cost = II

The total operating costs per year = OP_1

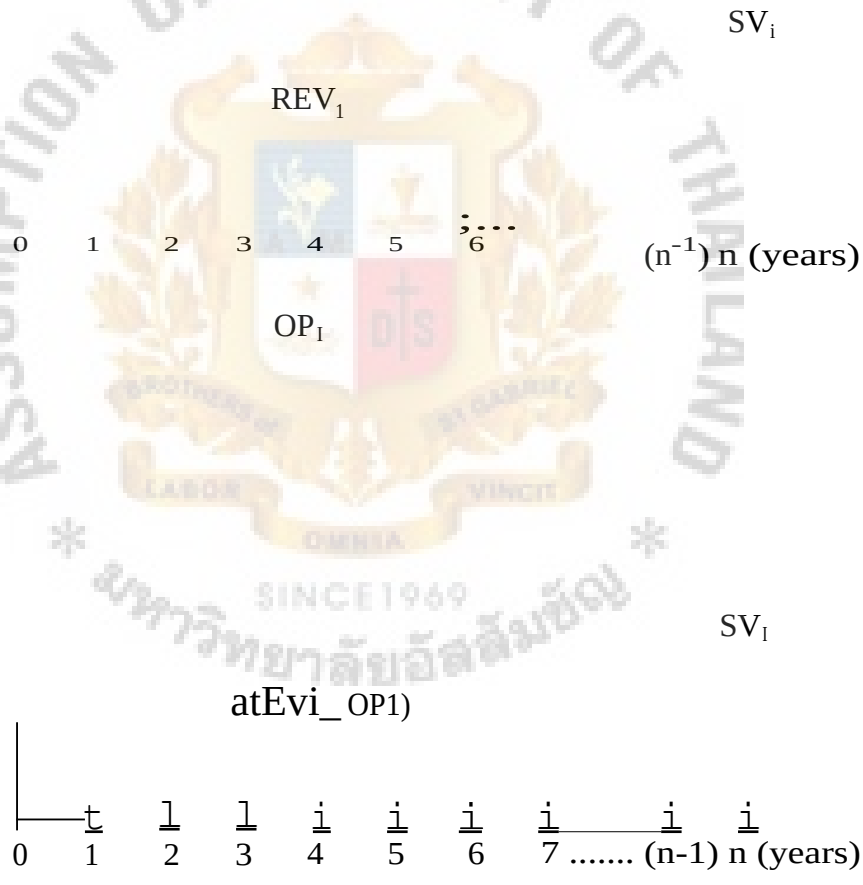
The revenues per year = REV

The life time of truck

The salvage value = SV_I

The cost of capital = i °A) per year

Its cash flow will be set in Figure 5_.11:



Cost of capital = i% per year

Figure 5.11. Cash Flow of Investment 1 (IVIIRR)

X $(REV_I\text{-}OP_1)$

TV = SV_1 + (REVi-OPI)(F/A,i%,n)

I_1 TV(P/F,$MIRR_1$%,n)

TV41+$MIRR_1$yi

Calculate $MIRR_1$ from this equation.

- Investment 2.

The initial cost = I_2

The total operating costs per year = OP_2

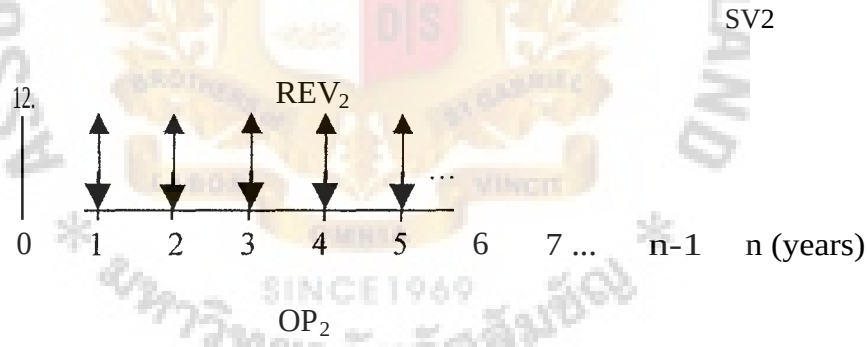
The revenues per year = REV_2

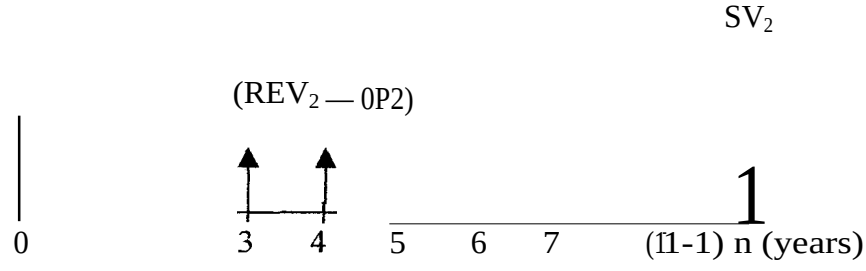
The life time of truck

The salvage value = SV_2

The cost of capital = i % per year

Its cash flow will be set in Figure 5,12:





The cost of capital = i % per year

Figure 5.12. Cash Flow of Investment 2 (MIRR)

X (REV2-0P2)

$TV = SV_2 + (REV_2\text{-}OP_2)(F/A,i\%,n)$

$TV(P/F,MIRR_2\%,n)$

$12 = TV/(1+MIRR_2)^{\circ}$

Calculate $MIRR_2$ from this equation.

If MEM > $MIRR_2$ then alternative 1 is accepted and alternative 2 is rejected.

If $MIRR_1$ < $MIRR_2$ then alternative 2 is 4ceeptIct 4.11 alternative 1 is rejected.

VI. COST ESTIMATION

In this chapter, equations from research of TRRL (Transport and Road Research Laboratory) will be introduced. And it will be applied in calculating the operating cost of heavy-duty truck (10-wheel truck and tractor & semi-trailer). TRRL's equations are proper in this report because the results of equations are the quantity value and it will be easy to understand and consider (monetary value). But the factors in these equations should be changed properly with topography of Thailand.

In this report, the interesting point is the cost of trader. In a trader's view, the operating cost is the most important because it effects business profit or loss.

A. Operating Cost of Truck and Tractor & Semi-Trailer (Abyaka, 1976)

For both of them, the operating cost of business consists of:

- Running costs.
  - Fuel consumption.
  - Lubricating oil consumption.
  - Vehicle maintenance parts consumption.
  - Vehicle maintenance labor hours.
  - Tire consumption.
  - Vehicle depreciation.
  - Crew hours.
- Standing costs is about 25% of Running costs.

B. Factors in Considering the Operating Cost (Abyaka, 1976)

- Rise and Fall (RS&F). This factor is the inclination of road. If the inclination of road is plus , it means the slope of road will increase. If the inclination of road is minus, it means the slope of road will decrease. Such as: Rise 1%, it means the 100 meters of length in horizontal, the height of road will increase 1 meter. Fall 1%, it means the 100 meters of length in horizontal, the height of road will decrease 1 meter. This is the effect to fuel consumption of vehicle. The more slope, the more fuel consumption.
- Vehicle speeds (V). The speed of vehicle effects the fuel consumption of vehicle. The fuel consumption will increase, if the speed increases.
- Power to weight ratio (P/VV). This factor is the ratio of the power of vehicle engine with the gross vehicle weight. For the same vehicle, the PW ratio will be low, if the load of vehicle is high and the PW ratio will be high, if the load of vehicle is low, This factor effects the fuel consumption of vehicle. if the load of vehicle is high (PW ratio is low), the fuel consumption will be high. If the load of vehicle is low (PW ratio is high), the fuel consumption will be low.
- Gross Vehicle Weight (GVW). It means the total weight of vehicle and the weight of load. This factor effects the fuel consumption and the wear of tire. The fuel consumption and the wear of tire will be high, if GVW is high or the load of vehicle is high. The fuel consumption and the wear of tire will be low, if GVW is low or the load of vehicle is low.
- Roughness (R). This factor will show the status of road. It shows the roughness of road. If the road is built well or very well, the roughness will be low. If the road is built badly or very old, the roughness will be high, This factor effects the vehicle

maintenance period, the wear of vehicle engine, the wear of tire, and the labor hour in maintenance. If the roughness of road is high, the maintenance period will be long, the engine will be much wear, the tires will be wear rapidly, and the labor hour in maintenance will be long per time.

- Cumulative kilometres (K). It means the cumulative distance of vehicle in using. This factor effects the times for maintenance. If the cumulative kilometres of vehicle is high, it shows that the engine and other parts of vehicle will be more wear, and the times for maintenance will be often.
- Average annual kilometres (KA). It means the average distance of vehicle in one year. This factor effects the wear of vehicle and life of vehicle.
- Vehicle age in year or life time of vehicle. Vehicle age in year is about 8 to 10 years. If more than 10 years, the salvage value of vehicle will be zero.
- Vehicle price (VP). This factor effects estimating depreciation of vehicle.

C. <u>The Relationship between Each Operating Cost and Factors That Related</u> (Abyaka, 1976)

Running Cost

- The Fuel Consumption (FL). The fuel consumption depends on vehicle speed, rise and fall, gross vehicle weight (GVW), and power to weight (PW).

  - The relationship between the fuel consumption and vehicle speed (From TRRL).

Given:

FL = The fuel consumption (liters /1,000 km.)

V = Vehicle speed (km/h)

a_0, a_1, a_2 = Constant (real number)

$$FL = + a_i/V +$$

The relationship between the fuel consumption and rise & fall of road (From TRRL).

Given:

RS = Rise (%)

Fall (%)

a_3, a_4 = Constant (real number)

$$FL = a_3kS - a_4F$$

The relationship between the fuel consumption and gross vehicle weight (GVW)(From TRRL).

Given:

GVW = Gross Vehicle Weight (Tons)

a_5, a_6 = Constant (real number)

$$FL = a5^{a6Gvw1/2}$$

The relationship the fuel consumption and the power to weight ratio (P/W). (From 1RRL)

Given:

PW = Power to Weight Ratio

(Horse powers / Tons)

a_7, a_8 = Constant (real number)

$$FL = a_7 \; a_8(PW)$$

From the relationship between the fuel consumption and each factor that discussed above, the fmal equation of the fuel consumption with all factors are:

$$FL = a_o + a_i/V + a2V^2 + a_3RS — a_4F + as^{4\_a6G\text{-}m\text{-}1/2} + a_7 — a_8(PW)$$

$$FL = (a_o + a_5 + a_7) + aiN + a2V^2 + a3RS = a4F^{a6Gvw1/2} — a_8(PW)$$

Given:

$(a_o + a_5 + a_7)$ = C_o

a_1 C_1

a_2 = C2

a_3 C3

a_4 = C4

a6 = Cs

a_8

1.13 = Correlation Factor

(Obtained from TRRL's experiment)

$$FL = [C_0 + C_i/V + C_2V^2 + C_3RS - C_4F + C_5GVW^{1/2} - C_6(PW)] * 1.13$$

This fuel equation can be used for Thailand condition because:

• Road surface of Thailand and Kenya (experiment place) is the same. It is asphalt road. The structure of road of Thailand and Kenya is the same (Data from department of state highway).

• At experiment place, Kenya, the slope of road has three types: smooth route, low slope route, and high slope route. The gradient (%) of them are no more than 4%, 6%, and 8% respectively. In Thailand, the gradient (%) of them are no more than 1.5%, 3.5%, and 6.5% respectively_ It is the same limit in two countries. (Data from department of state highway).

• Power and load of truck used in Kenya (experiment place) and Thailand is the same range (Data from department of state highway).

• In experiment, the velocity range is 5 - 100 km/h. It is the same range for Thailand: smooth route (80-100 lun/h), low slope route (60-80 km/h), and high slope route (50-60 km/h) (Data from department of state highway).

From these reasons, the TRRL's fuel consumption can be used in Thailand.

In experiment:

- Test 1. Truck is used that is a heavy-duty truck. Its weight with no load is 7.5 tons (GVW). Its engine power is 190 hp. Its power to weight ratio (PAW) is 25.333 (-190/7.5).

The route in this test is the smooth route (RS = 0, F = 0).

At any speed, the results are show as follows:

Velocity (V) (km/h)	Fuel consumption (FL) (Liters /1,000 km)
40	125.09
50	133.17
60	145.56
70	161.62
80	181.00

In real, speed of heavy truck is between 5 — 100 km/h. It is safety range of speed for big vehicle (Data from heavy-duty truck drivers).

And data from Highways Department:

- Limit velocity in smooth route == 80-100 km/h
- Limit velocity in low slope route = 60-80 km/h
- Limit velocity in high slope route = 50-60 km/h

So, the range of speed in testing should be 40 to 80 km/h.

$$C_o + \frac{C_i}{40} + 40^2 C_2 + (0)C_3 \; (0)C_4 + V7.5\, C_5\; 25.333\, C_6 = 125.09 \text{ ---(1)}$$

$$C_o + \frac{1}{50} + 50^2\, C_2 + (0)C_3 - (0)C_4 + J7.5\, C_5 - 25.333\, C_6 = 133.17 \text{ ---(2)}$$

$$C_o + \frac{1}{60} + 60^2 C_2 + (0)C_3 \quad (0)C_4 \; 47.5 \; C_5 \; 25.333 \; C_6 = 145.56 \quad (3)$$

$$C_o + \frac{}{70} \; 70^2 C_2 + (0)C_3 - (0)C_4 \; 47.5 \; C_5 - 25.333 \; C_6 = 161.61 \quad (4)$$

$$C_o + \frac{1}{80} + 80^2 C_2 + (0)C_3 - (0)C_4 + 47.5 \; C_5 - 25.333 \; C_6 = 181.00 \quad (5)$$

$$\begin{vmatrix} 1 & 1/40 & 40^2 & V7.5 & -25.333 \\ 1 & 1/50 & 50^2 & 173 & -25.333 \\ 1 & 1/60 & 60^2 & V7.5 & -25.333 \\ 1 & 1/70 & 70^2 & 1/7.5 & -25.333 \\ 1 & 1/80 & 80^2 & V7.5 & -25.333 \end{vmatrix} \begin{vmatrix} C_o \\ C_1 \\ C2 \\ C_5 \\ C \end{vmatrix} = \begin{vmatrix} 125.09 \\ 135.17 \\ 145.56 \\ 161.61 \\ 81.00 \end{vmatrix}$$

Solve this matrix by matrix technique:

C_o = -48.6

C_1 = 903

C_2 = 0.014

C_5 = 69.2

C_6 = 2.4

Replace in

$$IL = [\, C_o + C_1/V + C_2V^2 + C_3RS - C_4F + C_5GVW^{1/2} - C_6(^1/W)$$

It becomes

$$FL = \{ -48.6 + 903/V + 0.014V^2 + C_3RS - C_4F + 69.2GVW^{1/2} - 2.4(P/W)$$

- Test 2. Truck used is a heavy-duty truck. Its weight with no load is 7.5 tons (GVW), Its engine power is 190 hp. Its power to weight ratio (P/W) is 25.333 (-190/7.5).

The speed in this test is 50, 70, and 80 kin/b.

From TRRL's experiment:

At any slope route condition, the results are show as follows:

Speed = 50 km/h

RS	Fuel consumption (FL), liters/1,000 km
10	176.79
20	220,41
30	264.03
40	307.65
50	351.27
60	394.89
70	438,51
80	482.13

The gradient of real road is: smooth route (no more than 4%, RS=40), low slope route (no more than 6%, RS=60), and high slope route (no more than 8%, RS=80). So, TRRL's experiment, RS is between 10 to 80 for covering all range of gradient. And velocity 50 km/h is represent to moving in smooth route.

$$-48.6 + \frac{0}{50} + 50^{-} * 0.014 + 10 * C_3 - (0)C_4 - 4^{3}73 * 69.2 - 25.333 * 2.4 = 176.79$$

$$-48.6 + \frac{903}{50} + -502 * 0.014 + 20 * C_3 - (0)C_4 + 1775 * 69.2 - 25.333 * 2.4 = 220.41$$

$$-48.6 + \frac{903}{50} + 50^2 * 0.014 + 30 * C_3 - (0)C_4 + \sqrt{7.5} * 69.2 - 25.333 * 2.4 = 264.03$$

$$-48.6 + 50^3 + 50^2 * 0.014 + 40 * C_3 - (0)C_4 + \sqrt{7.5} * 69.2 - 25.333 * 2.4 = 307.65$$

$$-48.6 + \frac{903}{50} + 50^2 * 0.014 + 50 * C_3 - (0)C_4 + \sqrt{7.5} * 69.2 - 25.333 * 2.4 = 351.27$$

$$-48.6 + \frac{903}{50} + 50^2 * 0.014 + 60 * C_3 - (0)C_4 + \sqrt{7.5} * 69.2 - 25.333 * 2.4 = 394.89$$

$$-48.6 + \frac{903}{50} + 50^2 * 0.014 + 70 * C_3 - (0)C_4 + 7.5 * 69.2 - 25.333 * 2.4 = 438.51$$

$$-48.6 + \frac{903}{50} + 50^2 * 0.014 + 80 * C_3 - (0)C_4 + 7.5 * 69.2 - 25.333 * 2.4 = 482.13$$

$$C_3 = 4.362$$

Speed = 70 km/h

RS	Fuel consumption (FL), liters/1,000 kin
10	205.23
20	248.85
30	292.47
40	336.09
50	379.71
60	423.33
70	466.95
80	510.57

The gradient of real road is: smooth route (no more than 4%, RS=40), low slope route (no more than 6%, RS=60), and high slope route (no more than 8%, RS=80). So, TRRL's experiment, RS is between 10 to 80 for covering all range of gradient. And velocity 70 km/h is represent to moving in low slope route.

$$-48.6 + \frac{903}{70} + 70^2 * 0.014 + 10 * C_3 - (0)C_4 + 1/7.5 * 69.2 - 25.333 * 2.4 = 205.23$$

$$-48.6 + \frac{903}{70} + 70^2 * 0.014 + 20 * C_3 - (0)C_4 + -.17.5 * 69.2 - 25.333 * 2.4 = 248.85$$

$$-48.6 + \frac{903}{70} + 70^2 * 0.014 + 30 * C_3 - (0)C_4 + 1/7.5 * 69.2 - 25.333 * 2.4 = 292.47$$

$$-48.6 + \frac{903}{70} + 70^2 * 0.014 + 40 * C_3 - (0)C_4 + 117.5 * 69.2 - 25.333 * 2.4 = 336.09$$

$$-48.6 + \frac{903}{70} + 70^2 * 0.014 + 50 * C_3 \quad (0)C_4 + 117.5 * 69.2 - 25.333 * 2.4 = 379.71$$

$$-48.6 + \frac{903}{70} + 70^2 * 0.014 + 60 * C_3 - (0)C_4 + 117.5 * 692 - 25.333 * 2.4 = 423.33$$

$$-48.6 + \frac{903}{70} + 70^2 * 0.014 + 70 * C_3 - (0)C_4 + 1/7.5 * 69.2 - 25.333 * 2.4 = 466.95$$

$$-48.6 + \frac{903}{70} + 70^2 * 0.014 + 80 * C_3 - (0)C_4 + -N73 * 69.2 - 25.333 * 2.4 = 510.57$$

$$C3 = 4.362$$

Replace in

$$FL - [-48.6 + 903/V + 0.014V^2 + C_3RS - C_4F + 69.2GVW^{1/2} - 2.4(P/W)$$

It become to be

$$FL = [-48.6 + 903/V + 0.014V^2 + 4.362RS - C_4F + 69.2GVW^{1/2} - 2.4(P/W)$$

Speed = 80 km/h

RS	Fuel consumption (FL), liters/1,000 km
10	224.62
20	268.24
30	311.86
40	355.48
50	399.10

60	442.72
70	486.34
80	529.96

The gradient of real road is: smooth route (no more than 4%, RS=40), low slope route (no more than 6%, RS=60), and high slope route (no more than 8%, RS=80). So, TRRL's experiment, RS is between 10 to 80 for covering all range of gradient. And velocity 80 km/h is represent to moving in high slope route.

$$-48.6+\frac{903}{80}+80^{2*}\ 0.014+10*C_3-(0)C_4+\ /7.5*69.2-25.333*2.4\ =224.62$$

$$-48.6+\frac{903}{80}+80^{2}*0.014+20*C_3-(0)C_4+117.3*69.2-25.333*2.4=268.24$$

$$-48.6+\frac{903}{80}+80^{2}*0.014+30*C_3-(0)C_4+1,F775*69.2-25.333*2.4=311.86$$

$$-48.6+\frac{903}{80}+80^{2}*0.014+40*C_3-(0)C_4+V7.5*69.2-25.333*2.4=355.48$$

$$-48.6+\frac{\ }{80}+80^{2}*0.014+50*C_3-(0)C_4+,/7.5*69.2-25.333*2.4=399.10$$

$$-48.6+\frac{903}{80}+802*0,014+60*C3-(0)C_4\overline{+A7.3*}69,2-25,333*2,4\ =\ 442/2$$

$$-48.6+\frac{20}{80}3+80^{2}*0.014+70*C_3-(0)C_4\overline{+,/7.5*}69.2-25.333*2.4\ =\ 486.34$$

$$-48.6+\frac{903}{80}+80^{2}*0.014+80*C_3-(0)C_4\overline{+17.5*}69.2-25.333*2.4\ =\ 529.96$$

$$C_3 = 4.362$$

Replace in

$$FL = [\ -48.6+903/V+0.014V^2 \pm C_3RS - C_4F + 69.2GVW^{112} - 2.4(P/W)$$

It becomes

$$FL = [\ -48.6+903/V+0.014V^2 + 4.362RS - C_4F + 69.2GVW^{I/2} - 2.4(P/W)$$

- Test 3. Truck used is a heavy-duty truck. Its weight with no load is 7.5 tons (GVW). Its engine power is 190 hp. Its power to weight ratio (P/W) is 25.333 (=190/7,5).

The speed in this test is 72 km/h.

From TRRL's experiment:

At any fall route condition, the results are show as follows:

Speed = 72 km/h

Fall	Fuel consumption (FL), liters/1,000 km
10	146.89
20	128,55
30	110,21
40	91.87
50	73.53
60	55.19
70	36.85
80	18.51

The gradient of real road is: smooth route (no more than 4%, RS=40), low slope route (no more than 6%, RS=60), and high slope route (no more than 8%, RS=80), So, TRRL's experiment, .F is between 10 to 80 for covering all range of gradient (climbing down). And velocity 72 km/h is represent to moving on all types of route.

For fall route TRRL test at velocity 72 km/h only because it is safe for this condition.

$$-48.6 + \frac{903}{72} + 72^2 * 0.014 + (0)C_3 - 10 * C_4 - N/73 * 69.2 - 25.333 * 2.4 = 146.89$$

$$-48.6 + \frac{903}{72} + 72^2 * 0.014 + (0)C_3 - 20 * C_4 -,/7.5 * 69.2 - 25,333 * 2.4 = 128.55$$

$$-48.6 + \frac{903}{72} + 72^{24} 0.014 + (0)C_3 - 30 * C_4\ 47.5 * 69.2 - 25.333 * 2.4 = 110.21$$

$$-48.6 + \frac{903}{72} + 72^2 * 0.014 + (0)C_3 - 40 * C_4 - V7.5 * 69.2 - 25.333 * 2.4 = 91.87$$

$$-48.6 + \frac{903}{72} + 72^2 * 0.014 + (0)C_3 - 50 * C_4 - 117.5 * 69.2 - 25.333 * 2.4 = 73.53$$

$$-48.6 + \frac{903}{72} + 72^2 * 0.014 + (0)C_3 - 60 * C_4 - 1/7.5 * 69.2 - 25.333 * 2.4 = 55.19$$

$$-48.6 + \frac{903}{72} + 72^2 * 0{,}014 \quad (0)C_3 - 70 * C_4 - V7.5 * 69.2 - 25.333 * 2.4 = 36.85$$

$$-48.6 + \frac{902}{03} + 72^2 * 0.014 + (0)C_3 - 70 * C_4 \; 47.5 * 69.2 - 25.333 * 2.4 = 36.85$$

C4 1,834

Replace in

$$FL = [\, -48.6 + 903/V + 0.014V^2 + 4.362RS - C_4F + 69.2GVW^{112} - 2.4(P/W)$$

It becomes

$$FL = [\, -48.6 + 903/V + 0.014V^2 + 4.362RS - 1.834F + 69.2GVW^{1/2} - 2.4(P/W)\,]$$

But in the real condition, the fuel consumption is more than the result that obtained from the equation. So, the result from this equation must be multiplied with correlation factor for obtaining the more exact result when compared to the real result.

The correlation factor that obtained from TRRL's experiment is equal 1.13 . So, the final equation for calculating the fuel consumption is:

$$FL = [\, -48.6 + 903/V + 0.014V^2 + 4.362RS - 1.834F - 69.2GVW^{1/2} - 2.4(P/W)\,] * 1.13$$

This equation can be used for Thailand condition.

- The Lubricating Oil Consumption (Liters/1,000, kilometers). This data is obtained from the real use, or interviews with traders_

• The Vehicle Maintenance Parts Consumption (PC). This vehicle maintenance parts consumption will depend on vehicle price (VP), cumulative kilometer (K), and roughness (R).

Given:

PC = The vehicle maintenance parts consumption (Baht/km.)

VP = Vehicle price (Baht)

Cumulative kilometer (km.)

Roughness (mm./km.)

Graph show relation ship between PC/(VP*K) and R from TRRL' s experiment:

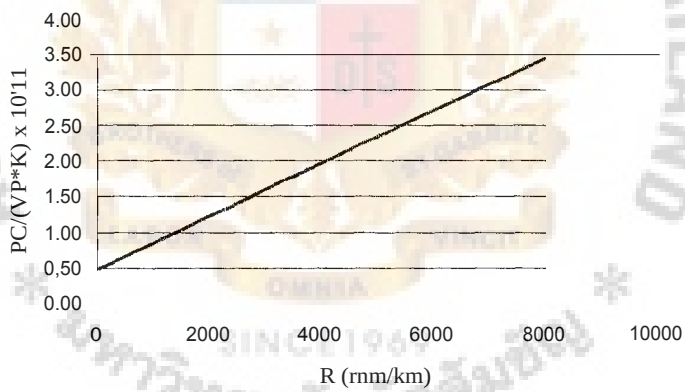


Figure 61 Show Relationship Between PC/(VP*K) and .R

From Figure 6.1, it show that higher roughness route the term of PC/(VP*K) will higher. That part of truck will be more damaged, if the route is highly rough.

With Linear regression technique

$$PC = (0.48 + 0.00037R)*(VP*K)*10''^{11}$$

This equation can be used for Thailand condition because R of road in Thailand is 1,800 mm/km (it is in testing range of TRRL's experiment).

The roughness of each road surface (From Department of Transportation)

Type of road surface	Roughness (mmlkm)
1. Asphalt concrete road	1,800 (Thailand)
2. New surface road	2,400
3. Old surface road	2,700
4. New Gravel road	5,000
5. Old Gravel road	10,000

- The Vehicle Maintenance Labor Hours (LH). The vehicle maintenance labor hours will depend on the vehicle maintenance parts consumption (PC), vehicle price (VP), and roughness (R).

Given:

LH = The Vehicle Maintenance Labor Hours

(11/1(m.)

PC = The Vehicle Maintenance Parts Consumption

(Baht/kn.)

VP = The Vehicle Price (Baht)

The Roughness (mm.Ikm)

Graph show relation ship between LH/(PC/VP) and R from TRRL's experiment:

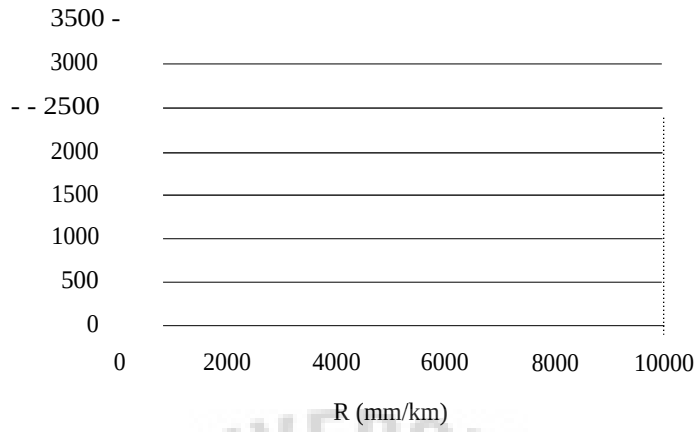


Figure 6,1 Show Relationship Between LHI(PC/VP) and R

The labor hour will depend on the roughness of route. The higher the roughness of route, the higher the labor hour.

With Linear regression technique

$$LH = (2{,}975 - 0.078\ R)*(PC/VP)$$

This equation can be used in Thailand condition because R of road in Thailand is 1,800 mm/km (it is in testing range of TRRL's experiment).

- The Tire Consumption (TC). The tire consumption will depend on the roughness (R), and the weight of vehicle (L).

Given:

TC = The Tire Consumption (tire/km.)

The Roughness (mm./km.)

The Weight of Vehicle or G.V.W. (Tons)

Graph show relationship between TC/L and R from TRRL's experiment:

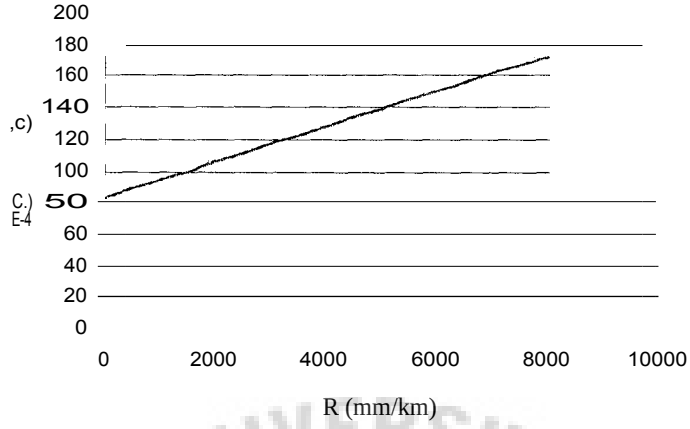


Figure 6.3. Show Relationship Between TC/L and R

From Figure 6.3, it shows that the tire will be more worn if the roughness of route is high.

With Linear regression technique

$$TC = (83 + 0.0112\ R)*L * 10^{-7}$$

This equation can be used for Thailand condition because R of road in Thailand is 1,800 mm/km (it is in testing range of TRRL's experiment).

- The Depreciation (DP). The depreciation will depend on the life of vehicle (Y).

Given:

DP The depreciation (% of Vehicle price)

Y The life of vehicle (years)

Data from TRRL, The life time of Heavy-duty truck is 9 years and % of Depreciation is shown as follows:

Year	DP (% of VP)
1	31%
2	16.3%
3	11.4%
4	9.1%
5	7.7%
6	6.7%
7	6.0%
8	5.4%
9	0

- Crew Hours (Baht/Person). This data is obtained from the real use, or interviews with trader.

Standing cost

This costs are consist of administration cost, insurance cost, registration tax, checking cost, etc.

Data from TRRL and Transportation company (Data from economists). It estimate value of standing as follows:

For big transportation company:

- Standing cost is about 25 — 45 % of running cost.

For small transportation company:

- Standing cost is about 10 - 25 % of running cost.

D. Summary Cost

Running cost

- Fuel consumption (liters/1,000 kin).

FL= j -48.6 + 903/V + $0.014V^2$ + 4.362RS =1.834F + $69.2GVW^{1/2}$ -- 2.4(P/W) J*1.13

- Lubricating oil consumption (liters/1,000 km). This data will be obtained from the real using, or interview from trader.

- Vehicle maintenance parts consumption (bahtlkm).

$$PC = (0.48 + 0.00037R)*(VP*K)*10^{-11}$$

- Vehicle maintenance labor hours (h/km).

$$LH = (2,975 — 0.078 R)*(PC/VP)$$

- Tire consumption (tire/km).

$$TC = (83 + 0.0112 R)*L * 10^{-7}$$

- Vehicle depreciation.

Year	DP (% of VP)
1	31%
2	16.3%
	11.4%
4	9.1%
5	7.7%
6	6.7%

7	6.0%
8	5.4%
9	0

- Crew hours (baht/person). This data is obtained from the real use, or interviews from trader.

Standing cost

For big transportation company:

- Standing cost is about 25 — 45 % of running cost.

For small transportation company:

- Standing cost is about l 0 -25 % of running cost.

Every equation can be applied to use in Thailand condition.

VII. CASE STUDIES (OPERATING COST ANALYSES)

In this chapter, total cost of 10-wheel truck and tractor & semi-trailer will be analyzed and will be compared together. Data in cases will be obtained from one transportation company - assumed name KTW company.

A. Company Profile

Name: KTW company

Product: Transportation service

Target Market: - Import - Export company

- Small business companies

- etc.

Service Area: Every province

Company Background, KTW company is a transportation service company. It is set up in year 1973 by Mr. Nugrunheng Sae Tai. Its service areas are the whole of Thailand. Types of goods that are transported by KTW company are varied and other many types: such as agricultural products, industrial products, etc. Market share is about 35% of all markets when compared to competitors.

There are 3 branches in Thailand to serve the customer:

- The first branch is the main office. It is in Bangkok. It is established in 1973.

- The second branch is the service center in the North. It is in Chiengmai. It is established in 1980.
- The third branch is the service center in South. It is in Phuket. It is established in 1984.

There are 185 employees. The employees are divided into:

- Administration Department = 25 persons
- Workers (drivers) = 70 persons
- Workers (crews) = 90 persons

There are 104 trucks to run business. Trucks are divided into:

- 6-wheel truck = 20 cars
- 10-wheel truck = 40 cars
- Tractor & Semi-trailer = 44 cars
- Total = 104 cars

Mission Statement. To be a leader in transportation service business.

Objectives of company

- To become the service leader.
- To ensure a quick, reliable response time, fast & efficient processing of orders and on time delivery,

Policies of company

- Do not compromise to quality based on quality policy.
- Respond to voice of customers.
- Build good relationship to customers.
- 4. To improve the efficiency of operation at low costs.

B. Analyzed Routes (Smith, Willbur, and Lyon, 1970)

Routes to be used in analyzing are:

- Bangkok - Chiengrai: Transfer through Highway No.1 .
- Bangkok — Ang Thong : Transfer through Highway No. 8.
- Bangkok - Khonkhean : Transfer through Highway No. 13.
- Bangkok - Khanchanaburi : Transfer through Highway No. 27.
- Bangkok - Phuket : Transfer through Highway No. 29.

C. Detail of Each Route (Smith, Willbur, and Lyon, 1970)

The physical details of each route that will be analyzed are the important data in estimating the operation cost and standing cost of business. So, these data will be shown in Table 7.1.

Table 7.1, Physical. Detail of each Route

Route	Distance (km.)			
	Smooth	Low Slope	High Slope	Total
1. Bangkok-Chiengrai	506.228	273.943	48.859	829.030
2. Bangkok-Ang Thong	107.159	-	-	107.159
3. Bangkok-Khonkhean	316.493	84.051	13.400	413.944
4. Bangkok-Khanchanaburi	129.109	-	-	129.109
5. Bangkok-Phuket	517.645	332.027	36.280	885.952

Assumption in calculation:

- Most of the roads in Thailand are Asphalt concrete road. So, The roughness of road will be 1,800 mm/km in calculation (Data from Department of state highway).
- From velocity limit of heavy-duty truck in Thailand: 80-100 km/h on smooth route, 60-80 km/h on low slope route, and 50-60 km/h on high slope route. In calculation, Heavy-duty truck with load: velocity = 80 km/h on smooth route, velocity -- 70 km/h on low slope route, and velocity = 56 km/h on high slope route, Heavy-duty truck with no load: velocity = 70 kmlh along the way (Data from Department of state highway).
- From road construction in Thailand: the gradient of smooth route is no more than 1.5%, the gradient of low slope route is no more than 3.5%, the gradient of high slope route is no more than 6.5%, In calculation, the gradient on smooth route is 1% (RS = 10) for every road, the gradient on low slope route is 3% (RS = 30) for every road, and the gradient on high slope route is 6% (RS = 60) for every road. (Data from Department of state highway)

D. Operating Cost (Running & standing costs) of Each Route

In this section, the important factors in calculation are:

- Gross Vehicle Weight (tons): GVW.
- Vehicle speed (m/s): V.
- Rise and Fall: RS & F.
- Power to weight ratio: P/W.
- Roughness (mm./km.): R.
- Vehicle price (baht): VP_
- Cumulative kilometres (km.): K.
- Average annual kilometres (km.): KA.
- Vehicle age in year: Y.
- Crew hour per year: C.

For 10-wheel truck and tractor & semi-trailer:

- 10-wheel truck.

VP = 1,500,000 baht

GVW = 10 tons (no load)

GVW = 21 tons (full load), load = 11 tons

BHP = 1951-P

Life time = 9 years

The price of 10-wheel truck (VP) consists of

- Truck head = 300,000 baht/unit
- Engine + Tax (220%) = 400,000 baht/unit
- Gear rate unit = 400,000 baht/set
- Chassis = 300,000 baht/unit
- Accessories 100,000 baht

  (Air pressure, Brake oil tube, Hydraulic equipment, etc.)
- Total = 1,500,000 baht/car

  (Data from Mitsubishi Motor company)
- A Tractor & Semi-trailer

  VP = 2,000,000 baht

  GVW = 16 tons (no load)

  GVW = 38 tons (full load), load = 22 tons

  BHP = 300 11P

  Life time = 9 years

The price of Tractor & Semi-trailer (VP) consists of

- Truck head = 400,000 baht/unit
- Engine + Tax (220%) = 550,000 baht/unit
- Gear rate unit (Gear slow) = 100,000 baht/set
- Gear rate unit (Gear normal) = 450,000 baht/set
- Chassis – 250,000 baht/unit
- The fifth wheel set = 100,000 baht/set

- Accessories = 150,000 baht

  (Air pressure, Brake oil tube, Hydraulic equipment, etc.)

- Total = 2,000,000 baht/car

  (Data from Mitsubishi Motor company)

Formula for Running costs:

- Fuel Consumption (FL), Liters/l)000 km.

$$FL= [-48.6 + 903/V + 0.014V^2 + 4.362RS = 1.834F + 69.2GVW^{1/2} = 2.4(P/W) *1.13$$

- Lubricating oil consumption (LB).

  LB = 5 liters/1,000 km (Data from interview truck driver)

- Vehicle maintenance parts consumption (PC), Baht/km.

$$PC = (0.48 + 0.00037R)*(VP*K)*10^{-11}$$

- Vehicle maintenance labor hour (LH), hours/km.

$$LH = (2,975 — 0.078 R)*(PC/VP)$$

  The average labor cost in Thailand is 75 Baht/hour.

- Tire consumption (TC), tire/km.

$$TC — (83 + 0.0112 R)*L * 10^7$$

- Vehicle depreciation (DP), Baht.

Year	DP (% of VP)
1	31%
2	16.3%
3	11,4%
4	9.1%
5	7.7%

6	6.7%
7	6,,0%
8	5.4%
9	0

- Crew hours (CH), hours/year.

  CH = 16 x 317 = 5,072 hours/year

  Average working hour = 16 h/day

  Average working day = 317 day/year

Formula for Standing cost: This costs are consist of administration cost, insurance cost, registration tax, checking costs, etc.

Data from Transportation company. It estimate value of standing as follows:

For big transportation company:

- Standing cost is about 25 — 45 ?/0 of running costs.

For small transportation company:

- Standing cost is about 10 - 25 % of running costs.

In Thailand: Most of transportation companies are small size. So, estimate standing costs for normal transportation company should be about 25% of running costs.

ROUTE BANGKOK-CHIENGRAI

Route in transportation Bangkok-Chiengrai and Chiengrai-Bangkok.

Total Distance	–	1,658.06	km. (829.03 x 2)
Transportation	=	1	rounds/week
	=	50	rounds/year
Average annual kilometer (KA)	=	1,658.06*50	
	=	82,903	km/year

From Bangkok to Chiengrai

- Load = 22 tons
- Total Distance = 829.030 km
- Smooth Route = 506.228 km
- Low Slope = 273.943 km
- High Slope = 48,859 km
- Average roughness all along the route (R) = 1 800 mm/km
- Average velocity on smooth route (V) = 80 km/h
- Average velocity on low slope route (V) = 70 km/h
- Average velocity on high slope route (V) = 56 km/h
- Average rise on smooth route (RS) = 10
- Average rise on low slope route (RS) = 30
- Average rise on high slope route (RS) = 60

From Chiengrai to Bangkok

- Load = 0 tons
- Total Distance = 829.030 km

- Smooth Route = 506.228 km
- Low Fall = 273.943 km
- High Fall = 48.859 km
- Average roughness all along the route (R) = 1,800 mm/km
- Average velocity all along route (V) = 70 km/h
- Average rise on smooth route (F) = 10
- Average rise on low fall route (F) = 30
- Average rise on high fall route (F) 60

10-wheel truck (2 cars for load 22 tons).

Calculate from 10-wheel truck 1 car.

Load 11 tons

From Bangkok to Chiengrai:

GVW = 21 tons

Average velocity on smooth route = 80 km/h

Average velocity on low slope route = 70 km/h

Average velocity on high slope route = 56 km/h

RS on smooth route = 10

RS on low slope route = 30

RS on high slope route = 60

P/W = 195/21

= 9,286

Ron all route	=	1,800 min/km
VP of truck	=	1,500,000 Baht
K	=	82,903 km/year
KA	=	82,903 km/year
Crew hour (CH)	=	5,072 hr/year
Life time	=	9 years

From Chiengrai to Bangkok:

GVW	=	10 tons
Average velocity all along the route	=	70 km/h
F on smooth route	=	10
F on low fall route	=	30
F on high fall route	=	60
P/W	=	195/10
		19.5
R on all route	=	1,800 mm/km

- Fuel consumption.

Forward to Destination

Smooth route	443.70 Liters/1,000 km	224.61 Liters
Low slope route	519.87 Liters/1,000 km	142.41 Liters
High slope route	642.88 Liters/1,000 km	31.41 Liters

Back to Bangkok

Smooth route	212.51 Liters/1,000 km	107.58 Liters
Low fall route	171.06 Liters/1,000 km	46.86 Liters
High fall route	108.89 Liters/1,000 km	5.32 Liters
	Total	558.20 Liters/round

Number of rounds/year = 50

Diesel oil = 8.7 baht/liter

Fuel consumption 242,814.87 baht/year

- Lubrication oil consumption.

LB = 5 liters/1,000 km

Number of rounds/year = 50

Lubrication oil price = 130 baht/liters

Distance = 1,658.06 km/round

Lubrication oil consumption 53,886.95 baht/year

- Parts consumption.

Year	K (km)	Commutative PC (baht/1,000 km)	Commutative PC * KA /1,000 (baht)	PC (baht) at year t
1	82,903	1,425.10	118,145.28	118,145.28
2	165,806	2,850.21	236,290.56	118,145.28
3	248,709	4,275.31	354,435.84	118,145.28
4	331,612	5,700.41	472,581.11	118,145.28
5	414,515	7,125.51	590,726.39	118,145.28
6	497,418	8,550.62	708,871.67	118,145.28
7	580,321	9,975.72	827,016.95	118,145.28
8	663,224	11,400.82	945,162.23	118,145.28
9	746,127	12,825.92	1,063,307.51	118,145.28

- Maintenance labor.

Year	Commutative PC (baht/1,000 km)	Commutative LH (h/1,000 km)	LH(h) at year t	LH(B)
1	1425.10	2.69	223,26	16744.73
2	2850.21	5.39	223.26	16744,73
3	4275.31	8.08	223.26	16744.73
4	5700.41	10.77	223.26	16744.73
5	7125.51	13.47	223.26	1674413
6	8550.62	16.16	223.26	16744.73
7	9975.72	18.85	223.26	16744.73
8	11400.82	21.54	223.26	16744.73
9	12825.92	24.24	223.26	1674433

- Tire consumption.

Forward to Destination

TC1 = 0.22 tire/1,000 km

Back to Bangkok

TC2 = 0.10 tire/1,000 km

Total = 0.32 tire/1,000_km

KA = 82,903 km/year

Tire Price = 5,000 baht/tire

Tire consumption 132,560.24 baht/year

- Vehicle Depreciation.

Year	Depreciation (baht) at year t
1	465,000.00
2	244,500,00
3	171,000.00
4	136,500.00
5	115,500.00
6	100,500.00

7	90,000.00
8	81,000.00
9	0.00

- Crew hours.

CH= 5,072 h/year

Crew cost= 25 bahtlh

Crew hours = 126,800.00 baht/year

- Total running costs.

Year	Total Running Costs (baht)
1	1,155,952.06
2	935,452.06
3	861,952.06
4	827,452.06
5	806,452.06
6	791,452.06
7	780,952.06
8	771,952.06
9	690,952.06

- Total operating costs.

Year	Standing costs (baht) (25% of running cost)	Total Operating costs (baht) (Running cost + Standing cost)
	288,988.02	1,444,940.08
2	233,863.02	1,169,315.08
3	215,488.02	1,077,440.08
4	206,863,02	1,034,315.08
5	201,613.02	1,008,065.08
6	197,863.02	989,315.08
7	195,238.02	976,190.08
8	192,988,02	964,940.08
9	172,738.02	863,690.08

(Operating cost for 10-wheel truck 1 car: load. 11 tons)

A Tractor & semi-trailer (load = 22 tons).

From Bangkok to Chiengrai:

GVW	=	38	tons
Average velocity on smooth route	=	80	km/h
Average velocity on low slope route	=	70	km/h
Average velocity on high slope route	=	56	km/h
RS on smooth route		10	
RS on low slope route	=	30	
RS on high slope route	=	60	

P/W	-	300/38
	-	7.895
R on all route	-	1,800 mm/km
VP of tractor & semi-trailer	-	2,000,000 Baht
K	-	82,903 km/year
KA	-	82,903 km/year
Crew hour (CH)	-	5,072 hr/year
Life time	-	9 years

From Chiengrai to Bangkok:

GVW	-	16 tons
Average velocity all along the route	-	70 km/h
F on smooth route		10
F on low fall route	=	30
F on high fall route	=	60
P/W	=	300/16
	-	18.75
R on all route	-	1,800 min/km

- Fuel consumption.

Forward to Destination

Smooth route	571.17 Liters/1,000 km	289.14 Liters
Low slope route	64'7.33 Liters/1,000 km	177.33 Liters
High slope route	770.34 Liters/1,000 km	37.64 Liters

Back to Bangkok

Smooth route	280.05 Liters/1,000 km	141.77 Liters
Low fall route	238.60 Liters/1,000 km	65.36 Liters
High fall route	176.43 Liters/1,000 km	8,62 Liters
	Total	719.86 Liters/round

Number of rounds/year = 50

Diesel oil = 8.7 baht/liter

Fuel consumption 313,139.63 Baht/year

- Lubrication oil consumption.

LB = 5 liters/1,000 km

Number of rounds/year = 50

Lubrication oil price = 130 Bahtlliters

Distance = 1,658.06 Km/round

Lubrication oil consumption 53,886.95 baht/year

- Parts consumption.

Year	K (km)	Commutative PC (baht/1,000 km)	Commutative PC *.KA /1,000 (baht)	PC (baht) at year t
1	82,903	1,900.14	157,527.04	157,527.04

2	165,806	3,800.27	315,054.08	157,527.04
3	248,709	5,700.41	472,581.11	157,527.04
4	331,612	7,600.55	630,108.15	157,527.04
5	414,515	9,500.68	787,635.19	157,527.04
6	497,418	11,400.82	945,162.23	157,527.04
7	580,321	13,300.96	1,102,689.26	157,527.04
8	663,224	15,201.09	1,260,216.30	157,527.04
9	746,127	17,101.23	1,417,743.34	157,527.04

- Maintenance labor.

Year	Commutative PC (baht/1,000 km)	Commutative LH (h/1,000 km)	LH(h) at year t	LH(B)
1	1900.14	2.69	223.26	16744.73
2	3800.27	5.39	223.26	16744.73
3	5700.41	8.08	223.26	16744.73
4	7600.55	10.77	223.26	16744.73
5	9500.68	13.47	223.26	16744.73
6	11400.82	16.16	223.26	16744.73
7	13300.96	18.85	223.26	16744.73
8	15201.09	21.54	223.26	16744.73
9	17101.23	24.24	223.26	16744.73

- Tire consumption,

Forward to Destination

TC1 = 0.39 tire/1,000 km

Back to Bangkok

TC2 = 0.17 tire/1,000 km

Total = 0.56 tire/1,000 km

KA = 82,903 km/year

Tire Price = 5,000 baht/tire

Tire consumption 230,91 L38 baht/year

- Vehicle depreciation.

Year	Depreciation (baht) at year t
1	620,000.00
2	326,000.00
3	228,000.00
4	182,000.00
5	154,000.00
6	134,000.00
7	120,000.00
8	108,000.00
9	0.00

- Crew hours.

CH= 5,072 h/year

Crew cost=- 25 Baht/h

Crew hours = 126,800.00 baht/year

- Total running costs.

Year	Total Running Costs (baht)
1	1,519,009.73
2	1,225,009.73
3	1,127,009.73
4	1,081,009.73
5	1,053,009.73
6	1,033,009.73
7	1,019,009.73
8	1,007,009.73
9	899,009.73

- Total operating costs.

Year	Standing costs (baht) (25% of running cost)	Total Operating costs (baht) (Running cost + Standing cost)
1	379,752.43	1,898,762.16
2	306,252.43	1,531,262.16
3	281,752.43	1,408,762.16
4	270,252.43	1,351,262.16

5	263,252,43	1,316,262 16
6	258,252.43	1,291,262,16
7	254,752.43	1,273,762.16
8	251,752.43	1,258,762.16
9	224 752.43	1,123,762,16

(Operating cost for Tractor & Semi-trailer 1 can load 22 tons)

ROUTE BANGKOK-ANG THONG

Route in transportation Bangkok- Ang Thong and Mg Thong-Bangkok

Total Distance = 214.318 km. (107.159 x 2)

Transportation = 7 rounds/week

= 350 rounds/year

Average annual kilometer (KA) = 214318*350

= 75,011.3 km/year

From Bangkok to Mg Thong

- Load = 22 tons
- Total Distance = 107,159 km
- Smooth Route = 107,159 km
- Average roughness all along the route (R) = 1,800 mm/km
- Average velocity on smooth route (V) = 80 km/h
- Average rise on smooth route (RS) = 10

From Ang Thong to Bangkok

- Load = 0 tons
- Total Distance = 107.159 km
- Smooth Route = 107.159 km
- Average roughness all along the route (R) = 1,800 mm/krn
- Average velocity all along _route (V) = 70 km/h
- Average Fall on smooth route (F) = 10

A 10-wheel 'truck (2 cars for load 22 tans).

Calculate from 10-wheel truck 1 car.

Load 11 tons

From Bangkok to Ang Thong:

GVW	=	21 tons
Average velocity on smooth route	=	80 km/h
RS on smooth route	-	10
P/W	-	195/21
	-	9.286
R on all route	-	1,800 mm/km
VP of truck	-	1,500,000 Baht
K		75,011.3 km/year
KA	-	75,011.3 km/year
Crew hour (CH)	-	5,072 hr/year

Life time	-	9 years
From Ang Thong to Bangkok:		
GVW	-	10 tons
Average velocity all along the route	-	70 km/h
F on smooth route	-	10
P/W	=	195/10
		19.5
R on all route	=	1,800 min/km

- Fuel consumption.

Forward to Destination

Smooth route	443.70 Liters/1,000 km	47,55 Liters
Low slope route	0.00 Liters/1,000 km	0,00 Liters
High slope route	0.00 Liters/1,000 km	0.00 Liters

Back to Bangkok

Smooth route	212.51 Liters/1,000 km	22.77 Liters
Low fall route	0.00 Liters/1,000 kin	0.00 Liters
High fall route	0.00 Liters/1,000 km	0.00 Liters

Total 70.32 Liters/round

Number of rounds/year = 350

Diesel oil = 8.7 baht/liter

Fuel consumption 214,120.08 baht/year

- Lubrication oil consumption.

LB = 5 liters/1,000 km

Number of rounds/year = 350

Lubrication oil price =130 Baht/liters

Distance = 214.32 Km/round

Lubrication oil consumption 48,757,35 baht/year

- Parts consumption.

Year	.K (km)	Commutative PC (baht/1,000 km)	Commutative PC * KA /1,000 (baht)	PC (baht) at year t
1	75,011	1,289.44	96,722.89	96,722.89
2	150,023	2,578.89	193,445.78	96,722.89
3	225,034	3,868.33	290,168.67	96,722.89
4	300,045	5,157.78	386,891.56	96,722.89
5	375,057	6,447.22	483,614.45	96,722.89
6	450,068	7,736.67	580,337.34	96,722.89
7	525,079	9,026.11	677,060.22	96,722.89
8	600,090	10,315.55	773,783.11	96,722.89
9	675,102	11,605,00	870,506.00	96,722.89

- Maintenance labor.

Year	Commutative PC (baht/1,000 kin)	Commutative LH (h/1,000 km)	LH(h) at year t	LH(B)
1	1289.44	2.44	182.78	13708.54
2	2578.89	4.87	182.78	13708.54
3	3868.33	7,31	182.78	13708.54
4	5157.78	9.75	182.78	13708.54
5	6447.22	12.18	182.78	13708.54
6	7736.67	14.62	182.78	13708.54
7	9026.11	17,06	182.78	13708,54
8	10315.55	19.49	182.78	13708.54
9	11605.00	21.93	182.78	13708.54

- Tire consumption.

Forward to Destination

TC1 = 0.22 tire/1,000 km

Back to Bangkok

TC2 = 0,10 tire/1,000 km

Total = 032 tire/1,000 km

KA = 75,011 km/year

TirePrice = 5,000 baht/tire

Tire consumption 119,941.57 baht/year

- Vehicle Depreciation.

Year	Depreciation (baht) at year t
1	465,000.00
2	244,500.00
3	171,000.00
4	136,500.00
5	115,500.00
6	100,500,00
7	90,000.00
8	81,000.00
9	0.00

- Crew hours.

CH= 5,072 h/year

Crew cost= 25 Baht/h

Crew hours = 1.26,800.00 baht/year

- Total running costs.

Year	Total Running Costs (baht)
	1,085,050.42
2	864,550.42
3	791,050.42
4	756,550,42

5	735 550 42
6	720,550A2
7	710,050.42
8	701,050.42
9	620,050.42

- Total operating costs.

Year	Standing costs (baht) (25% of running cost)	Total Operating costs (baht) (Running cost + Standing cost)
1	271,262.61	1,356,313.03
2	216,137.61	1,080,688.03
3	197,762,61	988,813.03
4	189,137.61	945,688.03
5	183,887.61	919,438.03
6	180,137.61	900,688.03
7	177 512.61	887,563.03
8	175,262.61	876,313.03
9	155,012.61	775,063.03

(Operating cost for 10-wheel truck 1 car: load 11 tons)

A Tractor & semi-trailer (load = 22 tons).

From Bangkok to Ang Thong:

GVW 38 tons

Average velocity on smooth route = 80 km/h

RS on smooth route	=	10
P/W	=	300/38
		7.895
R on all route	=	1,800 mm/km
VP of tractor & semi-trailer	=	2,000,000 Baht
		75,011,3 km/year
KA	=	75,011.3 km/year
Crew hour (CH)		5,072 hr/year
Life time	=	9 years

From Ang Thong to Bangkok:

GVW	=	16 tons
Average velocity all along the route	=	70 km/h
F on smooth route	=	10
P/W	=	300/16
		18.75
R on all route	-	1,800 mm/km

- Fuel consumption.

Forward to Destination

Smooth route	571.17 Liters/1,000 km	61.21 Liters
Low slope route	0.00 Liters/1,000 km	0.00 Liters
High slope route	0.00 Liters/1,000 km	0,00 Liters

Back to Bangkok

Smooth route	280.05 Liters/1,000 km	30.01 Liters
Low fall route	0.00 Liters/1,000 km	0.00 Liters
High fall route	0.00 Liters/1,000 km	0.00 Liters
	Total	91.22 Liters/round

Number of rounds/year = 350

Diesel oil = 8.7 baht/liter

Fuel consumption 277,750.49 Baht/year

- Lubrication oil consumption,

LB = 5 liters/1,000 km

Number of rounds/year = 350

Lubrication oil price = 130 Baht/liters

Distance = 214.32 Km/round

Lubrication oil consumption 48,757.35 baht/year

- Parts Consumption.

Year	K (km)	Commutative PC (baht/1,000 km)	Commutative PC * KA /1,000 (baht)	PC (baht) at year t
1	75,011	1,719.26	128,963.85	128,963.85
2	150,023	3,438.52	257,927.70	128,963.85

3	225,034	5,157.78	386,891.56	128,963.85
4	300,045	6,877,04	515,855.41	128,963.85
5	375,057	8,596.29	644,819.26	128,963.85
6	450,068	10,315.55	773,783.11	128,963.85
7	525,079	12,034.81	902,746,97	128,963.85
8	600,090	13,754.07	1,031,710,82	128,963.85
9	675,102	15,473.33	1,160,674.67	128,963.85

- Maintenance labor.

Year	Commutative PC (baht/1,000 km)	Commutative LH (h/1,000 km)	LH(h) at year t	LH(B)
1	1719.26	2.44	182.78	13708.54
2	3438.52	4.87	182.78	13708.54
3	5157.78	7.31	182.78	13708.54
4	6877.04	9.75	182.78	13708.54
5	8596.29	12.18	182.78	13708.54
6	10315.55	14.62	182.78	13708.54
7	12034.81	17.06	182.78	13708.54
8	13754.07	19.49	182.78	13708.54
9	15473.33	21.93	182.78	13708.54

- Tire consumption.

Forward to Destination

TC1 = 0.39 tire/1,000 km

Back to Bangkok

TC2 = 0.1.7 tire/1,000 km

Total = 0.56 tire/1,000 km

= 75,011 kin/year

Tire Price = 5,000 baht/tire

Tire consumption 208,930.47 baht/year

- Vehicle Depreciation.

Year	Depreciation (baht) at year t
1	620,000.00
2	326,000.00
3	228,000.00
4	182,000.00
5	154,000.00
6	134,000.00
7	120,000.00
8	108,000,00
9	0.00

- Crew hours.

CH= 5,072 h/year

Crew cost= 25 Baht/h

Crew hours = 126,800.00 Baht/year

- Total running costs.

Year	Total Running Costs (baht)
1	1,424,910.70
2	1,130,910.70
3	1,032,910.70
4	986,910.70
5	958,910.70
6	938,910.70
7	924,910.70
8	912,910.70
9	804,910.70

- Total operating costs.

Year	Standing costs (baht) (25% of running costs)	Total Operating costs (baht) (Running cost + Standing costs)
1	356,227.68	1,781,138.38
2	282,727.68	1,413,638.38
3	258,227.68	1,291,138.38
4	246,727,68	1,233,638.38

5	239,727.68	1,198,638.38
6	234,727.68	1,173,638.38
7	231,227.68	1,156,138.38
8	228,227.68	1,141,138.38
9	201,227.68	1,006,138.38

(Operating cost for Tractor & Semi-trailer 1 car: load 22 tons)

ROUTE BANGKOK-KHONKHEAN

Route in transportation Bangkok-Khonkhean and Khonkhean-Bangkok.

Total Distance	827.888	km. (413.944 x2)
Transportation	2 rounds/week	
	100 rounds/year	
Average annual kilometer (KA)	827.888*100	
	82,788.8	km/year

From Bangkok to Khonkhean:

- Load = 22 tons
- Total Distance = 413.944 km
- Smooth Route = 316.493 km
- Low Slope = 84.051 kt
- High Slope = 13.4 km
- Average roughness all along the route (R) = 1,800 mm/km
- Average velocity on smooth route (V) = 80 km/h

- Average velocity on low slope route (V) = 70 km/h
- Average velocity on high slope route (V) = 56 km/h
- Average rise on smooth route (RS) = 10
- Average rise on low slope route (RS) = 30
- Average rise on high slope route (RS) = 60

From Khonkhean to Bangkok:

- Load = 0 tons
- Total Distance = 413.944 km
- Smooth Route = 316.493 km
- Low Fall = 84.051 km
- High Fall = 13.4 km
- Average roughness all along the route (R) = 1,800 mm/km
- Average velocity all along route (V) = 70 km/h
- Average rise on smooth route (F) = 10
- Average rise on low fall route (F) = 30
- Average rise on high.fall route (F) = 60

A 10-wheel truck (2 cars for load 22 tons).

Calculate from 10-wheel truck 1 car.

Load 11 tons

From Bangkok to Khonkhean:

GVW	=	21 tons
Average velocity on smooth route	-	80 km/h
Average velocity on low slope route	-	70 km/h
Average velocity on high slope route	-	56 km/h
RS on smooth route	-	10
RS on low slope route		30
RS on high slope route	-	60
P/W	-	195/21
	=	9.286
R on all route	-	1,800 mm/km
VP of truck	-	1,500,000 Baht
K	=	82,788.8 km/year
KA	-	82,788.8 km/year
Crew hour (CH)	=	5,072 hr/year
Life time		9 years

From Khonkhean to Bangkok:

GVVV	-	10 tons
Average velocity all along the route	-	70 km/h
F on smooth route	=	10
F on low fall route	=	30
F on high fall route	=	60
P/W	=	195/10
	=	19:5

R on all route 1,800 min/km

- Fuel consumption.

Forward to Destination

Smooth route	452.13 Liters/1,000 km	143.10 Liters
low slope route	528.30 Liters/1,000 km	44.40 Liters
high slope route	65L31 Liters/1,000 km	8.73 Liters

Back to Bangkok

Smooth route	212.51 Liters/1,000 km	67.26 Liters
low fall route	171.06 Liters/1,000 km	14.38 Liters
high fall route	108.89 Liters/1,000 km	1.46 Liters
	Total	279.32 Liters/round

Number of rounds/year = 100

Diesel oil = 8.7 baht/liter

Fuel consumption 243,010.46 bahtlyear

- Lubrication oil consumption.

LB = 5 liters/1,000 km

Number of rounds/year = 100

Lubrication oil price = 130 Baht/liters

Distance = 827.89 km/round

Lubrication oil consumption 53,812.72 baht/year

- Parts consumption.

Year	K (km)	Commutative PC (baht/1,000 km)	Commutative PC * KA /1,000 (baht)	PC (baht) at year t
1	82,789	1,423.14	117,820.01	117,820.01
2	165,578	2,846.28	235,640.02	117,820.01
3	248,366	4,269.42	353,460.03	117,820.01
4	331,155	5,692.56	471,280.04	117,820.01
5	413,944	7,115.70	589,100.05	117,820.01
6	496,733	8,538.84	706,920.05	117,820.01
7	579,522	9,961.98	824,740.06	117,820.01
8	662,310	11,385.12	942,560.07	117,820.01
9	745,099	12,808.26	1,060,380.08	117,820.01

- Maintenance labor.

Year	Commutative PC (baht/1,000 km)	Commutative LH (h/1,000 km)	LH(h) at year t	LH(B)
1	1423.14	2.69	222.65	16698.63
2	2846.28	5.38	222.65	16698.63
3	4269.42	8.07	222.65	16698.63

4	5692.56	10:76	222.65	16698.63
5	7115.70	13A5	222.65	16698.63
6	8538.84	16.14	222.65	16698.63
7	9961.98	18.83	222.65	16698.63
8	11385.12	21.51	222.65,	16698.63
9	12808.26	24.20	222.65	16698.63

- Tire consumption.

Forward to Destination

TC1 = 0.23 Tire/1,000 km

Back to Bangkok

TC2 = 0.10 Tire/1,000 km

Total = 0.33 Tire/1,000 km

KA = 82,789 km/year

Tire Price = 5,000 baht/tire

Tire consumption 136,647.88 baht/year

- Vehicle Depreciation.

Year	Depreciation (baht) at year t
1	465,000.00
2	244,500.00
3	171,000.00
4	136,500.00
5	115 500.00
6	100,500.00
7	90,000.00
8	81,000.00
9	0.00

- Crew hours.

CH= 5,072 h/year

Crew cost= 25 Baht/h

Crew hours = 126,800.00 Baht/year

- Total running costs.

Year	Total Running Costs (baht)
1	1,159,789.70
2	939,289.70
3	865,789.70
4	831,289,70

5	810,289.70
6	795,289.70
7	784,789.70
8	775,789.70
9	694,789.70

- Total operating costs.

Year	Standing costs (baht) (25% of running costs)	Total Operating costs (baht) (Running cost + Standing costs)
1	289,947.43	1,449,737.13
2	234,822.43	1,174,112.13
3	216,447A3	1,082,237.13
4	207,822.43	1,039,112.13
5	202,572.43	1,012,862.13
6	198,822.43	994,112.13
7	196,197.43	980,987.13
8	193,947,43	969,737.13
9	173,697.43	868,487.13

(Operating cost for 10-wheel truck 1 car: load 11 tons)

A Tractor & semi-trailer (load = 22 tons).

From Bangkok to Khonkhean:

GVW	=	38 tons
Average velocity on smooth route	=	80 km/h
Average velocity on low slope route	=	70 km/h
Average velocity on high slope route	=	56 km/h
RS on smooth route	=	10
RS on low slope route	=	30
RS on high slope route		60
P/W	=	300/38
		7,895
R on all route	=	1,800 mm/km
VP of tractor & semi-trailer	=	2,000,000 Baht
K	=	82,788.8 km/year
KA	=	82,788.8 km/year
Crew hour (CH)	=	5,072 hr/year
Life time	=	9 years

From Khonkhean to Bangkok:

GVW	=	16 tons
Average velocity all along the route	=	70 km/h
F on smooth route	=	10
F on low fall route	=	30

F on high fall route		60
P/W	=	300/16
		18.75
R on all route	=	1,800 mm/km

- Fuel consumption.

Forward to Destination

Smooth route	571.17 Liters/1,000 km	180.77 Liters
low slope route	647.33 Liters/1,000 km	54.41 Liters
high slope route	770.34 Liters/1,000 km	10.32 Liters

Back to Bangkok

Smooth route	280.05 Liters/1,000 km	88.63 Liters
low fall route	238.60 Liters/1,000 km	20.05 Liters
high fall route	176.43 Liters/1,000 km	2.36 Liters
	Total	356.55 Liters/round

Number of rounds/year = 100

Diesel oil = 8.7 baht/liter

Fuel consumption 310,201.48 baht/year

- Lubrication oil consumption.

LB = 5 liters/1,000 km

Number of rounds/year = 100

Lubrication oil price = 130 Baht/liters

Distance = 827.89 km/round

Lubrication oil consumption 53,812.72 baht/year

- Parts Consumption.

Year	.K (km)	Commutative PC (baht/1,000 km)	Commutative PC * KA /1,000 (baht)	PC (baht) at year t
1	82,789	1,897.52	157,093.35	157,093.35
2	165,578	3,795.04	314,186.69	157,093.35
3	248,366	5,692.56	471,280.04	157,093.35
4	331,155	7,590.08	628,37138	157,09135
5	413,944	9,487.60	785,466.73	157,093.35
6	496,733	11,385.12	942,560.07	157,093.35
7	579,522	13,282.64	1,099,653.42	157,093.35
8	662,310	15,180.15	1,256,746.76	157,093.35
9	745,099	17,077.67	1,413,840.11	157,093.35

- Maintenance labor.

Year	Commutative PC (baht/1,000 km)	Commutative LH (h/1,000 km)	LH(h) at year t	LH(B)
1	1897.52	2.69	222.65	16698.63
2	3795.04	5.38	222.65	16698.63
3	5692.56	8M7	222,65	16698.63
4	7590.08	10.76	222.65	16698.63
5	9487.60	13.45	222.65	16698.63
6	11385.12	16.14	222.65	16698.63
7	13282.64	18.83	222,65	16698.63
8	15180.15	21.51	222.65	16698.63
9	17077.67	24.20	222.65	16698.63

- Tire consumption.

Forward to Destination

TC1 = 0.39 Tire/1,000 km

Back to Bangkok

TC2 = 0,17 Tire/1,000 km

Total = 0.56 Tire/1,000 km

KA = 82,789 km/year

Tire price = 5,000 baht/tire

Tire consumption 230,593.30 baht/year

- Vehicle Depreciation.

Year	Depreciation (baht) at year t
1	620,000.00
2	326,000.00
3	228,000.00
4	182,000.00
5	154,000.00
6	134,000 00
7	120,000.00
8	108,000.00
9	0.00

- Crew hours.

CH= 5,072 h/year

Crew cost= 25 bahtlh

Crew hours = 126,800.00 baht/year

- Total running costs.

Year	Total Running Costs(baht)
	1,515,199_48
2	1,221,199.48
3	1,123,199.48
4	1,077,199.48

5	1,049,199.48
6	1,029,199.48
7	1,015,199.48
8	1,003,199.48
9	895,199.48

- Total operating costs.

Year	Standing costs(baht) (25% of running costs)	Total Operating costs(baht) (Running cost + Standing costs)
1	378,799.87	1,893,999.35
2	305,299.87	1,526,499.35
3	280,799.87	1,403,999.35
4	269,299.87	1,346,499.35
5	262,299.87	1,311,499.35
6	257,299.87	1,286,499.35
7	253,799.87	1,268,999.35
8	250,799.87	1,253,999.35
9	223,799.87	1,118,999.35

(Operating cost for Tractor & Semi-trailer 1 car: load 22 tons)

ROUTE BANGKOK-KHANCHANABURI

Route in transportation Bangkok-Khanchanaburi and Khanchanaburi-Bangkok.

Total Distance		258.218	km. (129.109 x2)
Transportation		5	rounds/week
	= 250 rounds/year		
Average annual kilometer (KA)	=	258.218*250	
	= 64,554.5 km/year		

From Bangkok to Khanchanaburi:

- Load = 22 tons
- Total Distance = 129.109 km
- Smooth Route = 129,109 km
- Average roughness all along the route (R) --- 1,800 min/km
- Average velocity on smooth route (V) = 80 km/h
- Average rise on smooth route (RS) = 10

From Khanchanaburi to Bangkok:

- Load = 0 tons
- Total Distance = 129.109 km
- Smooth Route = 129.109 km
- Average roughness all along the route (R) = 1,800 mm/km
- Average velocity all along route (V) = 70 km/h
- Average rise on smooth route (F) = 10

A 10-wheel truck (2 cars for load 22 tons).

Calculate from 10-wheel truck 1 car.

Load	–	11 tons

From Bangkok to Khanchanaburi:

GVW	=	21 tons
Average velocity on smooth route	=	80 km/h
RS on smooth route	=	10
P/W	=	195/21
	-	9.286
R on all route	=	1,800 mm/km
VP of truck	=	1,500,000 Baht
	-	64,554.4 km/year
KA	=	64,554.4 km/year
Crew hour (CH)	=	5,072 hr/year
Life time	=	9 years

From Khanchanaburi to Bangkok:

GVW	=	10 tons
Average velocity all along the route	=	70 km/h
F on smooth route	=	10
P/W	=	195/10
	-	19.5

R on all route 1,800 mm/lm

- Fuel consumption.

Forward to Destination

Smooth route	443.70 Liters/1,000 km	57.29 Liters
low slope route	0.00 Liters/1,000 km	0.00 Liters
high slope route	0.00 Liters/1,000 km	0.00 Liters

Back to Bangkok

Smooth route	212.51 Liters/1,000 km	27.44 Liters
low fall route	0.00 Liters/1,000 km	0.00 Liters
high fall route	0.00 Liters/1,000 km	0,00 Liters
	Total	84.72 Liters/round

Number of rounds/year = 250

Diesel oil = 8,7 baht/liter

Fuel consumption 184,271.10 Baht/year

- Lubrication oil consumption.

LB = 5 liters/1,000 km

Number of rounds/year = 250

Lubrication oil price = 130 Bahtlliters

Distance = 258.22 km/round

Lubrication oil consumption 41,96036 baht/year

- Parts Consumption.

Year	K (km)	Commutative PC (baht/1,000 km)	Commutative PC * KA /1,000 (baht)	PC (baht) at year t
	64,554	1,109.69	71,635.38	71,635.38
2	129,109	2,219.38	143,270.76	71,63538
3	193,663	3,329.07	214,906.14	71,635.38
4	258,218	4,438.76	286,541.52	71,63538
5	322,772	5,548.45	358,176.90	71,635.38
6	387,326	6,658.14	429,812.29	71,635.38
7	451,881	7,767.83	501,447.67	71,635.38
8	516,435	8,877.52	573,083.05	71,635.38
9	580,990	9,987.21	644,718.43	71,635.38

- Maintenance labor.

Year	Commutative PC (baht/1,000 km)	Commutative LH (h/1,000 krn)	L11(h) at year t	LH(B)
1	1109.69	2.10	135.37	10152.88
2	2219.38	4.19	135.37	10152.88
3	3329.07	6.29	135.37	10152.88
4	4438,76	8.39	135.37	10152.88
5	5548.45	10.49	135.37	10152.88
6	6658.14	12.58	135.37	10152.88
7	7767.83	14.68	135.37	10152.88

8	8877.52	16.78	135.37	10152.88
9	9987.21	18.87	135.37	10152,88

- Tire consumption.

Forward to Destination

TC1 = 0.22 tire/1,000 km

Back to Bangkok

TC2 = 0.10 tire/1,000 km

Total = 0.32 tire/1000 km

KA = 64,554 kin/year

Tire price = 5,000 baht/tire

Tire consumption 103,221.19 baht/year

- Vehicle Depreciation.

Year	Depreciation (baht) at year t
1	465,000.00
2	244,500.00
3	171,000.00
4	136,500.00
5	115,500.00

6	100,500.00
7	90,000.00
8	81,000.00
9	0.00

- Crew hours.

CH= 5,072 h/year

Crew cost= 25 baht/h

Crew hours = 126,800.00 baht/year

- Total running costs,

Year	Total Running Costs(baht)
1	1,003,040.92
2	782,540.92
3	709,040.92
4	674,540.92
5	653,540.92
6	638,540.92
7	628,040.92
8	619,040.92
9	538,040.92

- Total operating costs.

Year	Standing costs(baht) (25% of running costs)	Total Operating costs(baht) (Running cost + Standing costs)
1	250,760.23	1,253,801.15
2	195,635.23	978,176.15
3	177,260.23	886,301.15
4	168,635.23	843,176.15
5	163,385.23	816,926.15
6	159,635.23	798,176.15
7	157,010.23	785,051.15
8	154,760.23	773,801 15
9	134,510.23	672,551.15

(Operating cost for 10-wheel truck 1 car: load 11 tons)

A Tractor & semi-trailer (load = 22 tons).

From Bangkok to Khanchanaburi:

GVW	=	38 tons
Average velocity on smooth route	=	80 km/h
RS on smooth route	=	10
P/W	=	300/38
	=	7.895
R on all route	=	1,800 mm/km
VP of tractor & semi-trailer	=	2,000,000 Baht
K	=	64,554.5 km/year

KA	=	64,554.5 km/year
Crew hour (CH)	=	5,072 hr/year
Life time	=	9 years

From Khanchanaburi to Bangkok:

GVVV	=	16 tons
Average velocity all along the route	=	70 km/h
F on smooth route	=	10
P/W	=	300/16
		18.75
R on all route	=	1,800 mm/km

- Fuel consumption.

Forward to Destination

Smooth route	571.17 Liters/1,000 km	73.74 Liters
low slope route	0.00 Liters/1,000 km	0.00 Liters
high slope route	0.00 Liters/1,000 km	0.00 Liters

Back to Bangkok

Smooth route	280.05 Liters/1,000 km	36.16 Liters
low fall route	0.00 Liters/1,000 km	0.00 Liters
high fall route	0.00 Liters/1,000 km	0.00 Liters

Total 109.90 Liters/round

Number of rounds/year = 250

Diesel oil = 8.7 baht/liter

Fuel consumption 239,031.24 Baht/year

- Lubrication oil consumption.

LB = 5 liters/1,000 km

Number of rounds/year = 250

Lubrication oil price = 130 Baht/liters

Distance = 258.22 km/round

Lubrication oil consumption 41,960.36 baht/year

- Parts Consumption.

Year	K (km)	Commutative PC (baht/1,000 km)	Commutative PC * KA /1,000 (baht)	PC (baht) at year t
1	64,554	1,479.59	95,513.84	95,513.84
2	129,109	2,959,17	191,027.68	95,513.84
3	193,663	4,438.76	286,541.52	95,513.84
4	258,218	5,918.35	382,055.36	95,513.84
5	322,772	7,397.93	477,569.21	95,513.84
6	387,326	8,877.52	573,083.05	95,513,84

7	451,881	10,357.11	668,596.89	95,513.84
8	516,435	11,836.69	764,110.73	95,513.84
9	580,990	13,316.28	859,624.57	95,513.84

- Maintenance labor.

Year	Commutative PC (baht/1,000 km)	Commutative LH (h/1,000 kin)	LH(h) at year t	LH(B)
1	1479.59	2.10	135.37	10152.88
2	2959.17	4.19	135.37	10152.88
3	4438.76	6.29	135.37	10152.88
4	5918_35	8.39	135.37	10152.88
5	7397.93	10.49	135.37	10152.88
6	8877.52	12.58	135.37	10152.88
7	10357.11	14.68	135.37	10152.88
8	11836.69	16.78	135.37	10152.88
9	13316.28	18.87	135.37	10152.88

- Tire consumption.

Forward to Destination

TC1 = 0.39 tire/1,000 km

Back to Bangkok

TC2 = 0.17 tire/1,000 km

Total = 0.56 tire/1,000 km

KA = 64,554 km/year

Tire price = 5,000 baht/tire

Tire consumption 179,804.66 baht/year

- Vehicle Depreciation.

Year	Depreciation (baht) at year t
	620,000.00
2	326,000.00
3	228,000.00
4	182,000,00
5	154,000.00
6	134,000.00
7	120,000.00
8	108,000,00
9	0.00

- Crew hours.

CH= 5,072 h/year

Crew cost= 25 baht/h

Crew hours = 126,800.00 baht/year

- Total running costs.

Year	Total Running Costs(baht)
1	1,313,262.99
2	1,019,262.99
3	921,262.99
4	875,262.99
5	847,262.99
6	827,262.99
7	813,262.99
8	801,262.99
9	693,262.99

- Total operating costs.

Year	Standing costs(baht) (25% of running costs)	Total Operating costs(baht) (Running cost + Standing costs)
1	328,315.75	1,641,578.74
2	254,815.75	1,274,078.74
3	230,315.75	1,151,578.74
4	218,815.75	1,094,078.74
5	211,815.75	1,059,078.74
6	206,815.75	1,034,078.74
7	203,315.75	1,016,578.74
8	200,315.75	1,001,578.74
9	173,315.75	866,578.74

(Operating cost for Tractor & Semi-trailer 1 car: load 22 tons)

ROUTE BANGKOK-PHUKET

Route in transportation Bangkok-Phuket and Phuket-Bangkok.

Total Distance	-	1,771,904 km. (885,952 x2)
Transportation	-	1 rounds/week
	-	50 rounds/year
Average annual kilometer (KA)	-	1,771.904*50
		= 88,595.2 km/year

From Bangkok to Phuket:

- Load = 22 tons
- Total Distance = 885.952 km
- Smooth Route = 517.645 km
- Low Slope = 332.027 km
- High Slope = 36.28 km
- Average roughness all along the route (R) = 1,800 rnm/km
- Average velocity on smooth route (V) = 80 km/h
- Average velocity on low slope route (V) = 70 km/h
- Average velocity on high slope route (V) = 56 km/h
- Average rise on smooth route (RS) = 10
- Average rise on low slope route (RS) = 30
- Average rise on high slope route (RS) = 60

From Phuket to Bangkok:

- Load = 0 tons
- Total Distance = 885.952 km
- Smooth Route = 517.645 km
- Low Fall = 332.027 km
- _High. Fall = 36.28 km
- Average roughness all along the route (R) = 1,800 mm/km
- Average velocity all along route (V) = 70 km/h
- Average fall on smooth route (F) = 10
- Average fall on low fall route (F) = 30
- Average fall on high fall route (F) = 60

A 10-wheel truck (2 cars for load 22 tons).

Calculate from 10-wheel truck 1 car.

Load 11 tons

From Bangkok to Phuket:

GVW	=	21	tons
Average velocity on smooth route	=	80	km/h
Average velocity on low slope route		70	kmfh
Average velocity on high slope route	=	56	km/h
RS on smooth route	=	10	
RS on low slope route	=	30	

RS on high slope route	=	60
P/W	=	195/21
	=	9.286
R on all route	=	1,800 mm/km
VP of truck	=	1,500,000 Baht
		88,595,2 km/year
KA	=	88,595.2 km/year
Crew hour (CH)	=	5,072 hr/year
Life time	=	9 years

From Phuket to Bangkok:

GVW	=	10 tons
Average velocity all along the route	=	70 km/h
F on smooth route	=	10
F on low fall route	=	30
F on high fall route	=	60
P/W	=	195/10
		19,5
R on all route	=	1,800 mm/km

- Fuel consumption.

Forward to Destination

Smooth route	443,70 Liters/1,000 km	229,68 Liters
low slope route	519_87 Liters/1,000 km	172_61 Liters

high slope route	642.88 Liters/1,000 km	2132 Liters
Back to Bangkok		
Smooth route	212.51 Liters/1,000 km	110.00 Liters
low fall route	171.06 Liters/1,000 km	56.80 Liters
high fall route	108.89 Liters/1,000 km	3.95 Liters
	Total	596.36 Liters/round

Number of rounds/year = 50

Diesel oil = 8.7 baht/liter

Fuel consumption 259,417.57 Baht/year

- Lubrication oil consumption.

LB = 5 liters/1,000 km

Number of rounds/year = 50

Lubrication oil price = 130 Baht/liters

Distance = 1,771,90 km/round

Lubrication oil consumption 57,586.88 baht/year

- Parts Consumption.

Year	K (km)	Commutative PC (baht/1,000 km)	Commutative PC * KA /1,000 (baht)	PC (baht) at year t
1	88,595	1,522.95	134,926.19	134,926.19
2	177,190	3,045.90	269,852.38	134,926.19
3	265,786	4,568.85	404,778.58	134,926.19
4	354,381	6,091.81	539,704.77	134,926.19
5	442,976	7,614.76	674,630.96	134,926.19
6	531,571	9,137.71	809,557.15	134,926.19
7	620,166	10,660.66	944,483.34	134,926.19
8	708,762	12,183.61	1,079,409.53	134,926.19
9	797,357	13,706.56	1,214,335.73	134,926.19

- Maintenance labor.

Year	Commutative PC (baht/1,000 km)	Commutative LH (h/1,000 km)	LH(h) at year t	LH(B)
1	1522.95	2.88	254.97	19123.09
2	3045.90	5.76	254.97	19123.09
3	4568.85	8.63	254.97	19123.09
4	6091.81	11.51	254.97	19123.09
5	7614.76	14.39	254.97	19123.09
6	9137.71	17.27	254.97	19123.09
7	10660.66	20.15	254.97	19123.09
8	12183.61	23.02	254.97	19123.09
9	13706.56	25.90	254.97	19123.09

- Tire consumption.

Forward to Destination

TC1 = 0,22 tire/1,000 km

Back to Bangkok

TC2 = 0.10 tire/1,000 km

Total = 0.32 tire/1,000 km

KA = 88,595 km/year

Tire price = 5,000 baht/tire

Tire consumption 141,661.95 baht/year

- Vehicle Depreciation.

Year	Depreciation (baht) at year t
1	465,000.00
2	244,500.00
3	171,000.00
4	136,500.00
5	115,500.00
6	100,500.00

7	90,000.00
8	81,000.00
9	0.00

- Crew hours.

CH= 5,072 h/year

Crew cost= 25 baht/h

Crew hours = 126,800.00 baht/year

- Total running costs.

Year	Total Running Costs (baht)
1	1,204,515.69
2	984,015.69
3	910,515.69
4	876,015.69
5	855 015.69
6	840,015.69
7	829,515.69
8	820,515.69
9	739,515.69

- Total operating costs.

Year	Standing costs (baht) (25% of running costs)	Total Operating costs (baht) (Running cost + Standing costs)
1	301,128.92	1,505,644.61
2	246,003.92	1,230,019.61
3	227,628.92	1,138,144.61
4	219,003.92	1,095,019.61
5	213,753.92	1,068,769.61
6	210,003.92	1,050,019.61
7	207,378.92	1,036,894.61
8	205,128.92	1,025,644.61
9	184,878.92	924,394.61

(Operating cost for 10-wheel truck 1 car: load 11 tons)

A Tractor & semi trailer (load = 22 tons).

From Bangkok to Phuket:

GVW	=	38	tons
Average velocity on smooth route	=	80	km/h
Average velocity on low slope route	=	70	km/h
Average velocity on high slope route	=	56	km/h
RS on smooth route	=	10	
RS on low slope route	=	30	
RS on high slope route	=	60	
P/W	=	300/38	

		7.895
R on all route	=	1,800 mm/km
VP of tractor & semi-trailer	=	2,000,000 Baht
K	=	88,595.2 km/year
KA	=	88,595.2 km/year
Crew hour (CH)	=	5,072 hr/year
Life time	=	9 years

From Phuket to Bangkok:

GVW	=	16 tons
Average velocity all along the route	=	70 km/h
F on smooth route	=	10
F on low fall route	=	30
F on high fall route	=	60
P/W	=	300/16
	=	18.75
R on all route	=	1,800 mm/km

- Fuel consumption.

Forward to Destination

Smooth route	571.17 Liters/1,000 km	295.66 Liters
low slope route	647.33 Liters/1,000 km	214.93 Liters
high slope route	770.34 Liters/1,000 km	27.95 Liters

Back to Bangkok

Smooth route	280.05 Liters/1,000 km	144.97 Liters
low fall route	238.60 Liters/1,000 km	79.22 Liters
high fall route	176.43 Liters/1,000 km	6.40 Liters
	Total	769,13 Liters/round

Number of rounds/year = 50

Diesel oil = 8.7 baht/liter

Fuel consumption 334,570.90 Baht/year

- Lubrication oil consumption.

LB = 5 liters/1,000 km

Number of rounds/year = 50

Lubrication oil price = 130 Baht/liters

Distance = 1,771.90 km/round

Lubrication oil consumption 57,586.88 baht/year

- Parts Consumption.

Year	K (km)	Commutative PC (baht/1,000 km)	Commutative PC * KA /1.,000 (baht)	PC (baht) at year t
1	88,595	2,030.60	179,901.59	179,901.59
2	177,190	4,061.20	359,803.18	179,901.59

3	265,786	6,091.81	539,704.77	179,901.59
4	354,381	8,122.41	719,606.36	179,901.59
5	442,976	10,153.01	899,507.94	179,901.59
6	531,571	12,183.61	1,079,409.53	179,901.59
7	620,166	14,214.21	1,259,311.12	179,901.59
8	708,762	16,244 82	1,439,212.71	179,901.59
9	797,357	18,275.42	1,619,114.30	179,901.59

- Maintenance labor.

Year	Commutative PC (baht/1,000 km)	Commutative LH (h/1,000 km)	LH(h) at year t	LH(B)
1	2030.60	2.88	254.97	19123.09
2	4061.20	5.76	254.97	19123.09
3	6091.81	8.63	254.97	19123.09
4	8122.41	11.51	254.97	19123.09
5	10153.01	14.39	254.97	19123.09
6	12183.61	17.27	254.97	19123.09
7	14214.21	20.15	254.97	19123.09
8	16244.82	23.02	254.97	19123.09
9	18275.42	25.90	254.97	19123.09

- Tire consumption.

Forward to Destination

TC1 = 0.39 tire/1,000 km

Back to Bangkok

TC2 = 0.17 tire/1,000 kin

Total = 0.56 tire/1,000 km

KA = 88,595 km/year

Tire price = 5,000 baht/tire

Tire consumption 246,765,98 baht/year

- Vehicle Depreciation.

Year	Depreciation (baht) at year t
1	620,000.00
2	326,000.00
3	228,000.00
4	182,000.00
5	154,000.00
6	134,000.00
7	120,000.00
8	108,000.00
9	0.00

- Crew hours.

CH= 5,072 h/year

Crew cost= 25 baht/h

Crew hours = 126,800.00 baht/year

- Total running costs.

Year	Total Running Costs (baht)
1	1,584,748.44
2	1,290,748.44
3	1,192,748.44
4	1,146,748.44
5	1,118,748.44
6	1,098,748.44
7	1,084,748.44
8	1,072,748.44
9	964,748.44

- Total operating costs.

Year	Standing costs (baht) (25% of running costs)	Total Operating costs (baht) (Running cost + Standing costs)
1	396,187.11	1,980,935.55
2	322,687.11	1,613,435.55
3	298,187.11	1,490,935.55
4	286,687.11	1,433,435.55

5	279,687.11	1,398,435.55
6	274,687.11	1,373,435.55
7	271,187.11	1,355,935.55
8	268,187.11	1,340,935.55
9	241,187.11	1,205,935.55

(Operating cost for Tractor & Semi-trailer 1 car: load 22 tons)

VIII. CASE STUDIES (CASH FLOW ANALYSES)

In this chapter, the costs in each case will be analyzed by financial techniques:

- NPW (Net Present Worth).
- EUAW (Equivalent Uniform Annual Worth).
- IRR (Incremental Rate of Return)

Costs in each case that will be calculated from many elements: Vehicle price, Standing cost, and Operating cost. Cash flow of cost for 10-wheel truck and tractor & semi-trailer will be set and analyzed.

Costs in using 10-wheel truck will be compared to cost in using tractor & semi-trailer for analyzing and selecting the proper alternative to transportation business. The proper alternative will effect to resource allocation: reduce fuel consumption, reduce road damaging, reduce pollution, etc.

Bangkok to Chiengrai

Load demand	22 tons

- 10-wheel truck.

Price	1,500,000 Baht/car
Load per car	11 tons
Number of cars	2 cars

Life time	9 years
MARR	15 %

Cash flow

Year	Total Operating costs (baht) (For 1 car: load 11 tons)	Total Operating costs (baht) (For 2 car: load 22 tons)
0	1,500,000.00	3,000,000.00
1	1,444,940.08	2,889,880.16
2	1,169,315.08	2,338,630.16
3	1,077,440.08	2,154,880.16
4	1,034,315.08	2,068,630.16
5	1,008,065.08	2,016,130.16
6	989,315.08	1,978,630.16
7	976,190.08	1,952,380.16
8	964,940.08	1,929,880.16
9	863,690.08	1,727,380.16

- Tractor & semi-trailer.

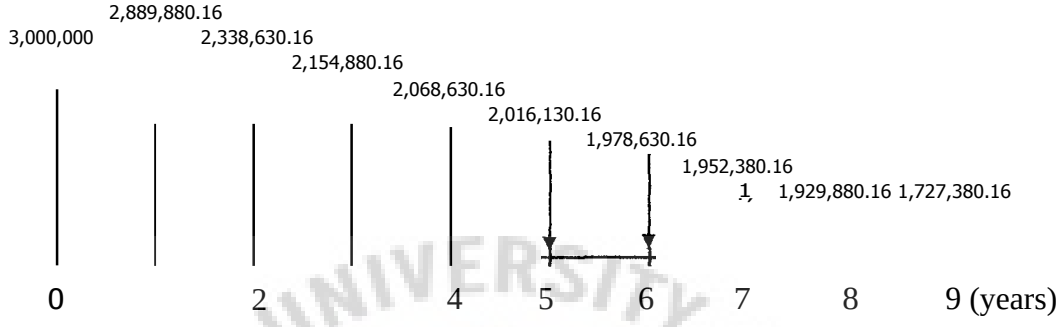
Price	2,000,000 Baht/car
Load per car	22 tons
Number of cars	1 cars
Life time	9 years
MARR	15%

Cash flow

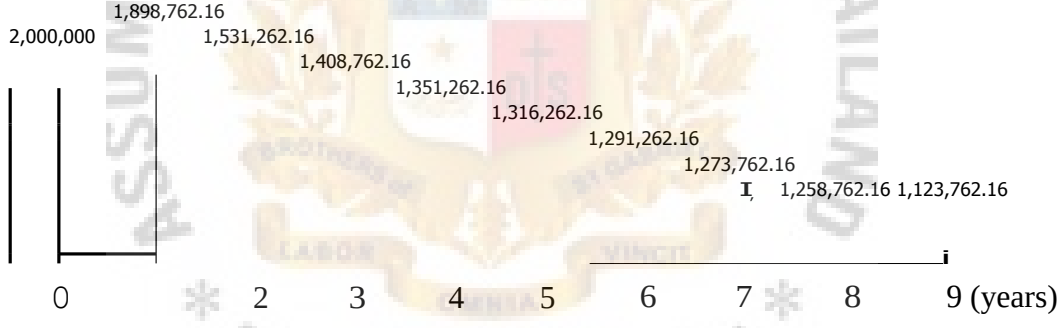
Year	Total Operating costs (baht) (For 1 car: load 22 tons)
0	2,000,000,00
1	1,898,762.16
2	1,531,262.16
3	1,408,762.16
4	1,351,26116
5	1,316,262.16
6	1,291,262,16
7	1,273,762.16

8	1,258,762.16
9	1,123,762.16

Cash Flow Diagram for 10-wheel truck.



Cash Flow Diagram for tractor & semi-trailer.



NPVIO-whe,e1 truck = 3,000,000 + 2,889,880.16 /(1+0.15) + 2,338,630.16 /(1+0.15)^2 + 2,154,880.16 41+0.15)^3 + 2,068,630.16 41+0.15)^4 + 2,016,130.16 41+0.15)^5 + 1,978,630.16 /(1+0.15)^6 + 1,952,380.16 41+0.15)^7 + 1,929,880.16 /(1+0.15)^8 +- 1,727,380.16 /(1+0.15)^9

13,594,566.29 baht

NPVsemi-trailer 2,000,000 + 1,898,762.16 1(1+0.15) +
1,531,262.16 /(1+0.15)^2 + 1,408,762.16 41+0.15)^3 +
1,351,262.16 /(1+0.15)^4 + 1,316,262.16 41+0.15)^5 +
1,291,262.16 41+0.15)^6 + 1,273,762.16 41+0.15)^7 +
1,258,762.16 /(1+0.15)^8 + 1,123,762.16 41+0.15)^9
8,930,276.72 baht

EUAW10-wheel truck = NPV10-wheel truck {0.15(1+0.15)9/[(1+0.15)9-1]}
= 2849,067.84 baht/year

EUAW s i-trailer = NPVsemi-trailer {O. 15(1+0. 15)^{9}4(1+0. 1 5)^{9}4])
= 1,871,553.95 baht/year

From calculation; the 10-wheel truck alternative is independent from the tractor & semi-trailer alternative. So, the IRR between 10-wheel truck and tractor & semi-trailer will not be found. It can be shown in Table 9.1 and figure 8.1.

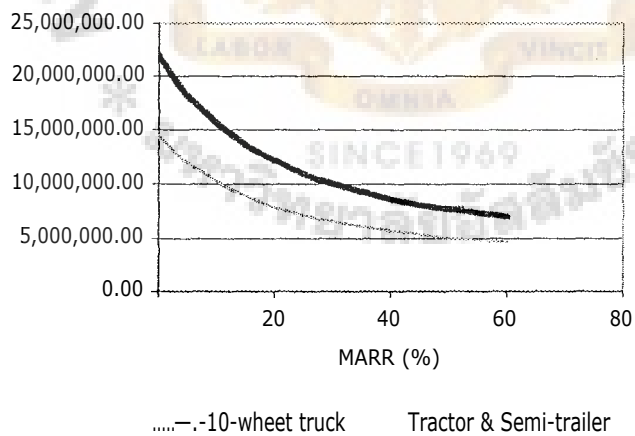


Figure 8.1. NPV at Any MARR (Bangkok-Chiengrai)

Table 9.1. NPV at Any MARR (Bangkok-Chiengrai)

MARR	10-wheel truck	Tractor & Semi-trailer
0	22,056,421.44	14,453,859.44
5	18,300,205.63	12,002,364.70
10	15,595,315.80	10,236,634.59
15	13,594,566.29	8,930,276.72
20	12,078,279.09	7,940,025.98
25	10,903,637.54	7,172,731.47
30	9,975,448.41	6,566,296.39
35	9,228,783.35	6,078,361.07
40	8,618,403.45	5,679,407.56
45	8,112,160.49	5,348,456.77
50	7,686,787.08	5,070,323.06
55	7,325,155.02	4,833,826.15
60	7,014,454.95	4,630,603.78

From figure 8.1, it shows that no interception point between 10-wheel truck line and tractor & semi-trailer line. The IRR of 10-wheel truck compared to tractor & semi-trailer cannot be calculated. It shows that at every MARR (minimum average rate of return), the 10-wheel truck's alternative total cost in NPV term will always more than the tractor & semi-trailer's total cost in NPV.

In this case, $NPV_{10\text{-whcel truck}} > NPV_{\text{semi-trailer}}$, at MARR = 15%

$EUAW_{\text{10-wheel truck}} > EUAW_{\text{semi-trailer}}$, at MARR = 15%

Total cost of 10-wheel truck > Total cost of tractor & semi-trailer (at any MARR, from figure 8.1).

So, the tractor & semi-trailer alternative is more economical than the 10-wheel truck alternative.

Bangkok to Ang Thong

Load demand 22 tons

- 10-wheel truck.

Price 1,500,000 Baht/car

Load per car 11 tons

Number of cars 2 cars

Life time 9 years

MARR 15%

Cash flow

Year	Total Operating costs (baht) (For 1 car: load 11 tons)	Total Operating costs (baht) (For 2 car: load 22 tons)
0	1,500,000.00	3,000,000.00
1	1,356,313.03	2,712,626.06
2	1,080,688.03	2,161,376.06
3	988,813.03	1,977,626.06
4	945,688.03	1,891,376.06
5	919,438.03	1,838,876.06
6	900,688.03	1,801,376.06
7	887,563.03	1,775,126.06
8	876,313.03	1,752,626.06
9	775,063.03	1,550,126.06

- Tractor & semi-trailer.

Price 2,000,000 Baht/car

Load per car 22 tons

Number of cars 1 cars

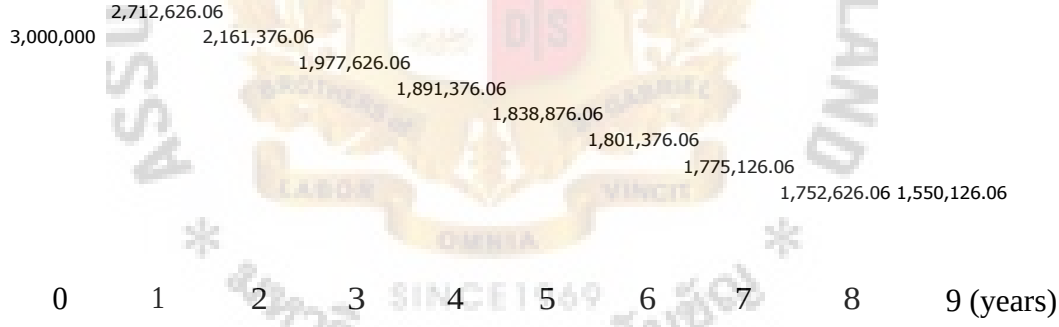
Life time 9 years

MARR 15 %

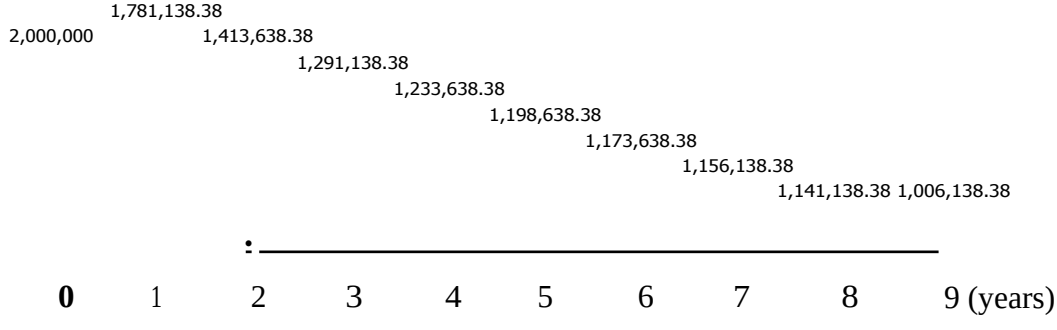
Cash flow

Year	Total Operating costs (baht) (For 1 car: load 22 tons)
0	2,000,000.00
1	1,781,13838
2	1,413,638.38
3	1,291,138.38
4	1,233,638.38
5	1,198,638.38
6	1,173,638.38
7	1,156,138.38
8	1,141,138.38
9	1,006,138.38

Cash Flow Diagram for 10-wheel truck.



Cash Flow Diagram for tractor & semi-trailer.



NPV10-wheel truck = 3,000,000 + 2,712,626.06 41+0.15) +
2,161,376.06 /(1+0.15)^2 + 1,977,626.06 41+0.15f +
1,891,376.06 41+0.15)^4 + 1,838,876.061(1+0.15)^5 +
1,801,376.06 /(1+0.15)^6 + 1,775,126.06 /(1+0.15) +
1,752,626.061(1+0.15)^8 + 1,550,126.061(1+0.15)^9
12,748,783.48 baht

NPVsemi-trailer = 2,000,000 + 1,781,138.38 41+0,15) +
1,413,638.38 /(1+0.15)^2 + 1,291,138.38 41+0.15)^3 +
1,233,638.381(1+0.15)^4 + 1,198,638.381(1+0.15)^5 +
1,173,638.38 /(1+0.15)^6 + 1,156,138.38 41+0.15f +
1,141,138.38 /(1+0.15)^8 + 1,006,138.38 /(1+0.15)^9
8,369,024.98 baht

EUAW10-wheel truck = NPV10-wheel truck [0.15(1+0.15)9/R1+0.15)9-1j}
= 2,671,813.74 baht/year

EUAWsemt-trailer = NPVsemt-trailer [0.15(1+0.15)9/R1+0.15)9-1D
= 1,753,930.17 baht/year

From calculation; the 10-wheel truck alternative is independent from the tractor & semi-trailer alternative. So, the ERR between 10-wheel truck and tractor & semi-trailer will not be found. It can be shown in Table 9.2 and figure 8.2.

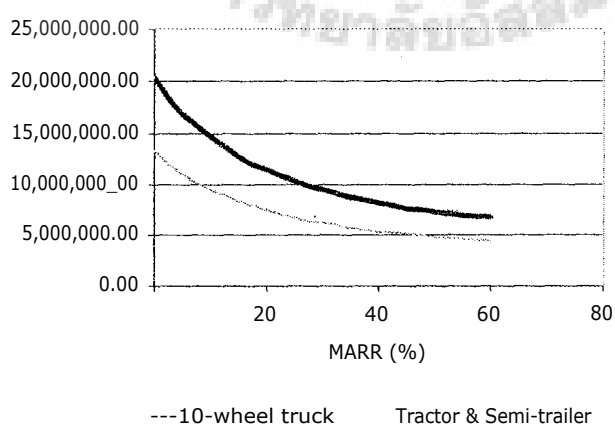


Figure 8.2. NPV at Any MARR (Bangkok-Ang Thong)

Table 92 NPV at Any MARR (Bangkok-Ang Thong)

MARR	10-wheel truck	Tractor & Semi-trailer
0	20,461,134.54	13,395,245.42
5	17,040,315.10	11,166,315.84
10	14,574,505.22	9,559,236.44
15	12,748,783.48	8,369,024.98
20	11,363,773.75	7,465,888.46
25	10,289,783.71	6,765,385.13
30	9,440,318.04	6,211,190.04
35	8,756,346.62	5,764,857.50
40	8,196,716.06	5,399,580.67
45	7,732,164.31	5,096,295.68
50	7,341,500.45	4,841,194.83
55	7,009,115.75	4,624,106.13
60	6,723,330.43	4,437,416.90

From figure 8.2, it shows that no interception point between 10-wheel truck line and tractor & semi-trailer line. The IRR of 10-wheel truck compared to tractor & semi-trailer cannot be calculated, but it shows that at every MARR (minimum average rate of return), the 10-wheel truck's alternative total cost in NPV term will always more than the tractor & semi-trailer's total cost in NPV,

hi this case, NPVia-wheei tuck > NM/serni-trailer at MARR =15%

EUAW1 0 -wheel truck > EUAWsenil_tmil,, , at MARR = 15%

Total cost of 10-wheel truck > Total cost of tractor & semi-trailer (at any MARR, from. figure 8.2).

So, the tractor & semi-trailer alternative is more economical than the 10-wheel truck alternative.

Bangkok to Khonkhean

Load demand 22 tons

- 10-wheel truck.

Price 1,500,000 Baht/car

Load per car 11 tons

Number of cars 2 cars

Life time 9 years

.MARR 15%

Cash flow

Year	Total Operating costs (baht) (For 1 car: load 11 tons)	Total Operating costs (baht) (For 2 car: load 22 tons)
0	1,500,000.00	3,000,000.00
1	1,449,737.13	2,899,474.26
2	1,174,112.13	2,348,224.26
3	1,082,237.13	2,164,474.26
4	1,039,112.13	2,078,224.26
5	1,012,862.13	2,025,724.26
6	994,112.13	1,988,224.26
7	980,987.13	1,961,974,26
8	969,737.13	1,939,474, 26
9	868,487,13	1,736,974.26

- Tractor & semi-trailer.

Price 2,000,000 Baht/car

Load per car 22 tons

Number of cars 1 cars

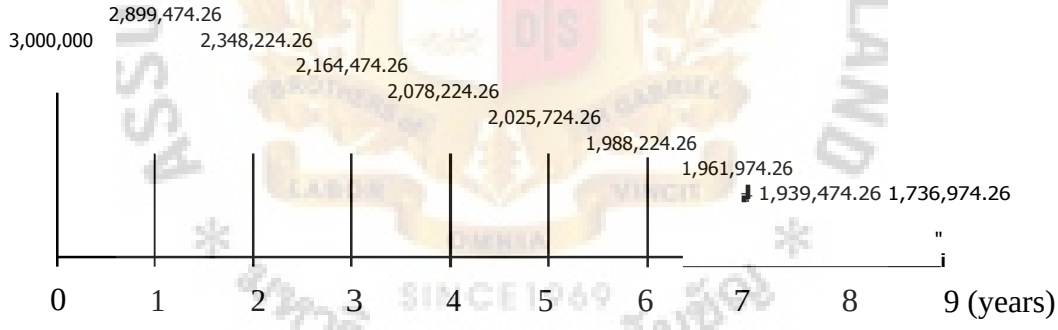
Life time 9 years

MARK 15 %

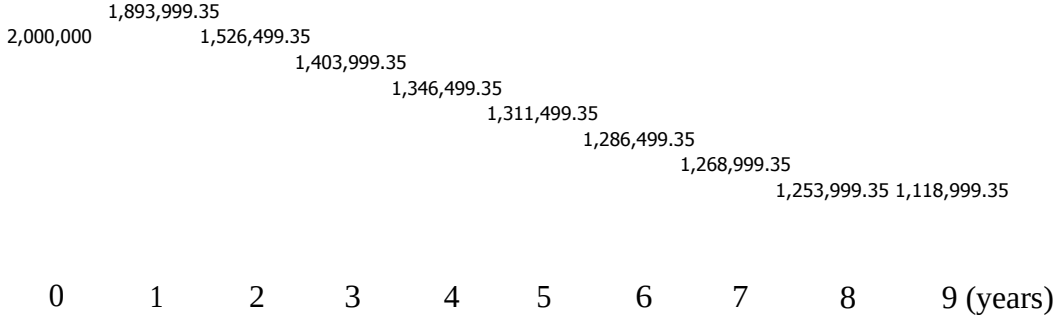
Cash flow

Year	Total Operating costs (baht) (For 1 car: load 22 tons)
0	2,000,000.00
1	1,893,999.35
2	1,526,499.35
3	1,403,999,35
4	1,346,499.35
5	1,311,499.35
6	1,286,499,35
7	1,268,999.35
8	1,253,999.35
9	1,118,999.35

Cash Flow Diagram for 10-wheel truck.



Cash Flow Diagram for tractor & semi-trailer.



NPVIO-wheel truck = 3,000,000 + 2,899,474.26 /(1+0.15) +
2,348,224.26 41+0.15)^2 + 2,164,474.26 41+0.15)^3 +
2,078,224.26 7(1+0.15)^4 + 2,025,724.26 41+0.15)^5 +
1,988,224.26 /(1+0.15)^6 + 1,961,974.26 41+0.15)^7 +
1,939,474.26 7(1+0.15)^8 + 1,736,974.26 41+0.15)^9
13,640,345.35 baht

NPVscmi-trailcr 2,000,000 + 1,893,999.35 41+0.15) +
1,526,499.35 /(1+0.15)^2 + 1,403,999.35 7(1+0.15)^3 +
1,346,499.35 41+0.15)^4 + 1,311,499.35 41+0.15)^5 +
1,286,499.35 7(1+0.15)^6 + 1,268,999.35 41+0.15)^7 +
1,253,999.35 7(1+0.15)^8 + 1,118,999.35 7(1+0.15)^9
8,907,550,57 baht

EUAW10-wheel truck = NPV10-wheel truck {0.15(1+0.15)94(1+0.15)94D
= 2,858,661.94 baht/year

EUAWsemi-trailer NPVsemi-trailer 0.15(1+0.15)94(1+0.15)9-1D
= 1,866,791.14 baht/year

From calculation; the 10-wheel truck alternative is independent from the tractor & semi-trailer alternative. So, the IRR between 10-wheel truck and tractor & semi-trailer will not be found. It can be shown in Table 9.3 and figure 8.3.

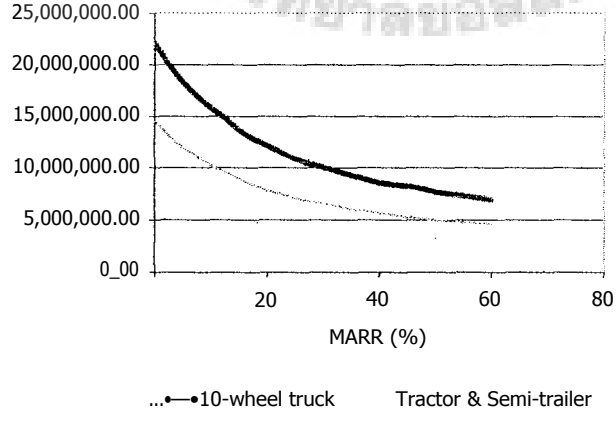


Figure 8.3. NPV at Any MARR (Bangkok-Khonkhean)

Table 9.3. NPV at Any MARR (Bangkok-Khonkhean)

MARR	10-wheel truck	Tractor & Semi-trailer
0	22,142,768.34	14,410,994.15
5	18,368,398.78	11,968,511.49
10	15,650,568.45	10,209,205.45
15	13,640,345.35	8,907,550.57
20	12,116,952.59	7,920,827.25
25	10,936,863.15	7,156,237.24
30	10,004,413.01	6,551,917.46
35	9,254,354.58	6,065,666.72
40	8,641,227.81	5,668,076.84
45	8,132,728.26	5,338,246.29
50	7,705,476.15	5,061,045.22
55	7,342,261.04	4,825,334.18
60	7,030,212.43	4,622,781.28

From figure 8.3, it shows that no interception point between 10-wheel truck line and tractor & semi-trailer line. The IRR of 10-wheel truck compared to tractor & semi-trailer cannot be calculated, but it shows that at every MARR (minimum average rate of return), the 10-wheel truck's alternative total cost in NPV term will always more than the tractor & semi-trailer's total cost in NPV.

In this case, $NPV_{10\text{-wheel truck}} > NPV_{\text{semi-trailer}}$, at MARR = 15%

$EUAW_{10\text{-wheel truck}} > EUAW_{\text{semi-trailer}}$, at MARR = 15%

Total cost of 10-wheel truck > Total cost of tractor & semi-trailer (at any MARR, from figure 8.3).

So, the tractor & semi-trailer alternative is more economical than the 10-wheel truck alternative.

Bangkok to Khanchanaburi

Load demand	22 tons

- 10-wheel truck.

Price	1,500,000 Baht/car
Load per car	11 tons
Number of cars	2 cars
Life time	9 years
MARR	15%

Cash flow

Year	Total Operating costs (baht) (For 1 car: load 11 tons)	Total Operating costs (baht) (For 2 car: load 22 tons)
0	1,500,000.00	3,000,000.00
1	1,253,801.15	2,507,602.30
2	978,176.15	1,956,352.30
3	886,301.15	1,772,602.30
4	843,176.15	1,686,352.30
5	816,926.15	1,633,852.30
6	798,176.15	1,596,352.30
7	785,051.15	1,570,102.30
8	773,801.15	1,547,602.30
9	672,551.15	1,345,102.30

- Tractor & semi-trailer.

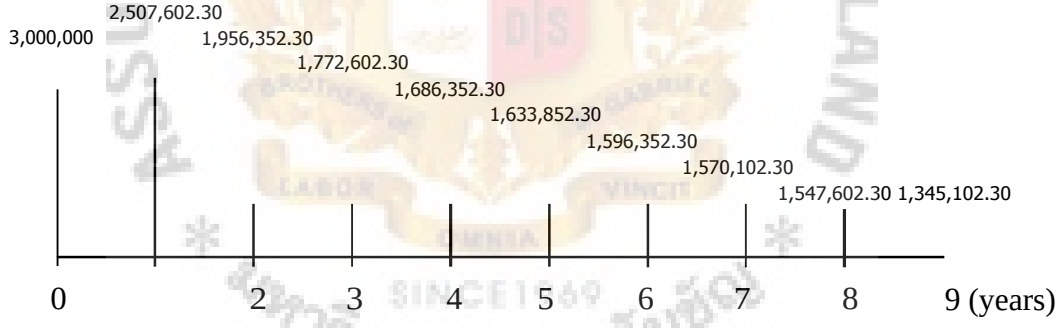
Price	2,000,000 Baht/car
Load per car	22 tons
Number of cars	1 cars
Life time	9 years

MARR 15 %

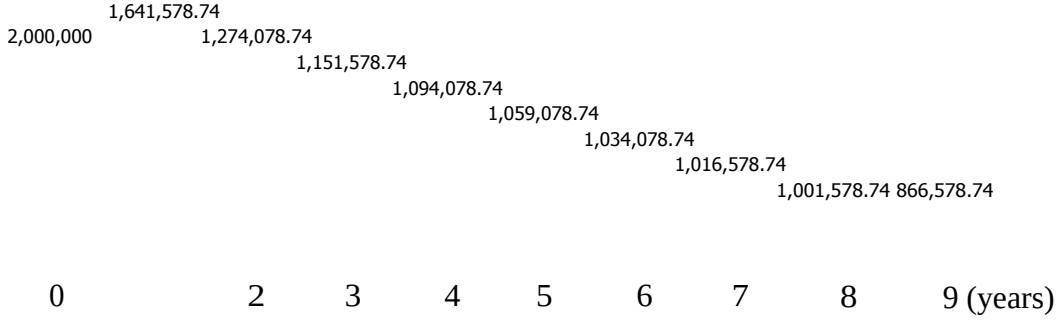
Cash flow

Year	Total Operating costs (baht) (For 1 car: load 22 tons)
0	2,000,000,00
1	1,641,578.74
2	1,274,078.74
3	1,151,578.74
4	1,094,078.74
5	1,059,078.74
6	1,034,078,74
7	1,016,578.74
8	1,001,578.74
9	866,578.74

Cash Flow Diagram for 10-wheel truck.



Cash Flow Diagram for tractor & semi-trailer.



NPVIO-wheel truck = 3,000,000 + 2,507,602.30 41+0,15) +
1,956,352.30 1(1+0.15)^2 + 1,772,602.30 41+0.15)^3 +
1,686,352.30/(1+0.15)^4 + 1,633,852.30 41+0.15)^5 +
1,596,352.30 /(1+0.15)^6 + 1,570,102.30 41+0.15)^7 +
1,547,602.30 /(1+0.15)^8 + 1,345,102.30 41+0.15)^9
= 11,770,495 baht

$NPV_{semi\_trailer}$ = 2,000,000 + 1,641,578.74 /(1+0.15) +
1,274,078.74 /(1+0.15)^2 + 1,151,578.74 41+0.15)^3 +
1,094,078.74 41+0.15)^4 + 1,059,078.74 41+0.15)^5 +
1,034,078.74 41+0.15)^6 + 1,016,578.74 41+0.15)^7 +
1,001,578.74 /(1+0.15)^8 + 866,578.74 1(1+0.15)^9
7,703,104.45 baht

EUAW10-wheel truck = NPV10-wheel truck {0.15(1+0.15)^9/[(1+0.15)^9=1])
= 2,466,789.98 baht/year

EUAW semi-trailer = NPVserni-trailer 0.15(1+0.15)9/[(1-1-0.15)9-1];
= 1,614,370.53 baht/year

From calculation; the 10-wheel truck alternative is independent from the tractor & semi-trailer alternative. So, the IRR between 10-wheel truck and tractor & semi-trailer will not be found. It can be shown in Table 9.4 and figure 8.4.

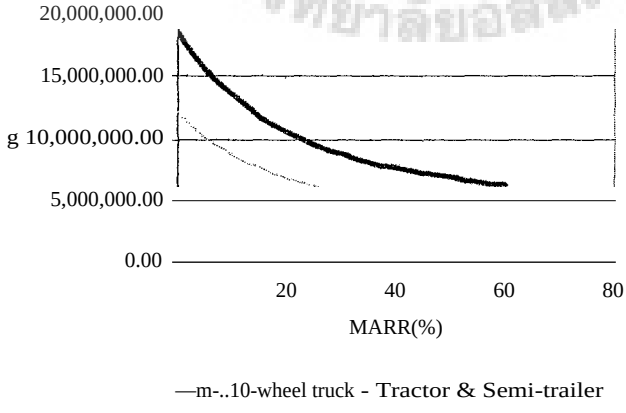


Figure 8.4. NPV at Any MARR (Bangkok-Khanchanaburi)

Table 9.4. NPV at Any MARR (Bangkok-Khanchanaburi)

MARR	10-wheel truck	Tractor & Semi-trailer
0	18,615,920.70	12,139,208.66
5	15,583 042.77 - -	10,174,350.81
10	13,393,768.50	8,755,509.15
15	11,770,495.41	7,703,104.45
20	10,537,329.84	6,903,328.23
25	9,579,759.96	6,282,072.08
30	8,821,351.03	5,789,859.30
35	8,209,895.20	5,392,888.11
40	7,708,964.67	5,067,568.37
45	7,292,635.72	4,797,108.64
50	6,942,119.21	4,569,336.08
55	6,643,563.93	4,375,275.06
60	6,386,596.64	4,208,202.27

From figure 8.4, it shows that no interception point between 10-wheel truck line and tractor & semi-trailer line. The ERR of 10-wheel truck compared to tractor & semi-trailer cannot be calculated, but it shows that at every MARR (minimum average rate of return), the 10-wheel truck's alternative total cost in NPV term will always more than the tractor & semi-trailer's total cost in NPV.

In this case, $NPV_{10\text{-whd truck}} >$, at MARR = 15%

$EUAW_{10\text{-wheel truck}} > EUAW_{\text{senai-trailer}}$, at MARR = 15%

Total cost of 10-wheel truck > Total cost of tractor & semi-trailer (at any MARR, from figure 8.4).

So, the tractor & semi-trailer alternative is more economical than the 10-wheel truck alternative.

Bangkok to Phuket

Load demand 22 tons

- 10-wheel truck.

Price 1,500,000 Baht/car

Load per car 11 tons

Number of cars 2 cars

Life time 9 years

MARR 15%

Cash flow

Year	Total Operating costs (baht) (For 1 car: load 11 tons)	Total Operating costs (baht) (For 2 car: load 22 tons)
0	1,500,000.00	3,000,000.00
1	1,505,644.61	3,011,289.22
2	1,230,019.61	2,460,039.22
3	1,138,144.61	2,276,289.22
4	1,095,019.61	2,190,039.22
5	1,068,769.61	2,137,539.22
6	1,050,019.61	2,100,039.22
7	1,036,894.61	2,073,789.22
8	1,025,644.61	2,051,289.22
9	924,394.61	1,848,789.22

Tractor & semi-trailer.

Price 2,000,000 Baht/car

Load per car 22 tons

Number of cars 1 cars

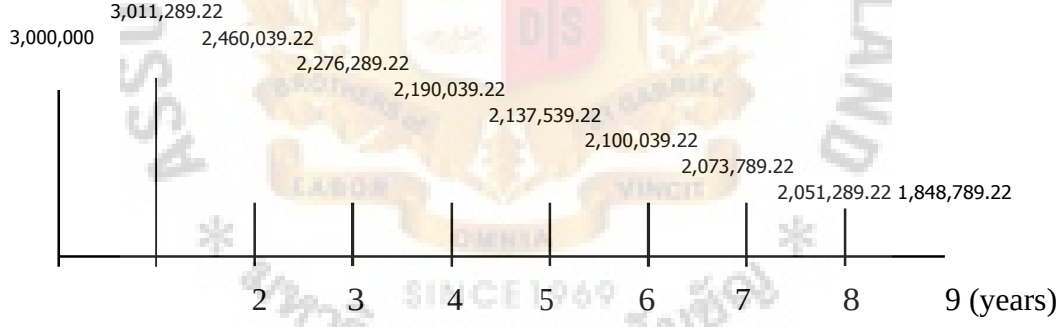
Life time 9 years

MARR 15 %

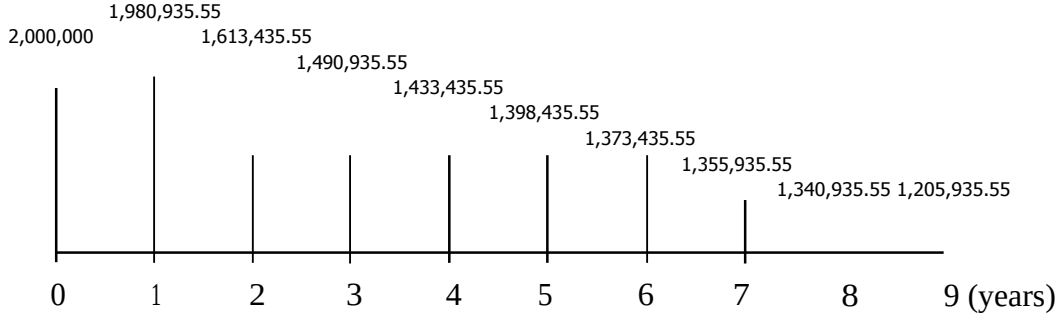
Cash flow

Year	Total Operating costs (baht) (For 1 car: load 22 tons)
0	2,000,000.00
1	1,980,935.55
2	1,613,435.55
3	1,490,935.55
4	1,433,435.55
5	1,398,435.55
6	1,373,435.55
7	1,355,935.55
8	1,340,935.55
9	1,205,935.55

Cash Flow Diagram for 10-wheel truck.



Cash Flow Diagram for tractor & semi-trailer.



NPV10-wheel truck = 3,000,000 + 3,011,289.22 /(1+0.15) + 2,460,039.22 41+0.15)^2 + 2,276,289.22 41+0.15)^3 + 2,190,039.22 41+0.15)^4 + 2,137,539.22 41+0.15)^5 + 2,100,039.22 41+0.15)^6 + 2,073,789.22 41+0.15)^7 + 2,051,289.22 41+0.15)^8 + 1,848,789.22 41+0.15)^9

14,173,879,81 baht

NPVseini-traikr = 2,000,000 + 1,980,935.55 41+0.15) + 1,613,435.55 /(1+0.15)^2 + 1,490,935.55 41+0.15)^3 + 1,433,435.55 41+0.15)^4 + 1,398,435.55 41+0.15)^5 + 1,373,435.55 /(1+0.15)^6 + 1,355,935.55 41+0.15)^7 + 1,340,935.55 41+0.15)^8 + 1,205,935.55 41+0.15)^9

9,322,373.95 baht

EUAW10-wheel truck = NPV10-wheel truck {0.15(1+0.15)%1+0.15)^{9}4]}

= 2,970,476.90 baht/year

EUAW semi-trailer = NPVsemi-trailer {0.15(1+0.15)9/K1+0.15)9-1D

= 1,953,727.34 baht/year

From calculation; the 10-wheel truck alternative is independent from the tractor & semi-trailer alternative. So, the IRR between 10-wheel truck and tractor & semi-trailer will not be found. It can be shown in table 9.5 and figure 8.5.

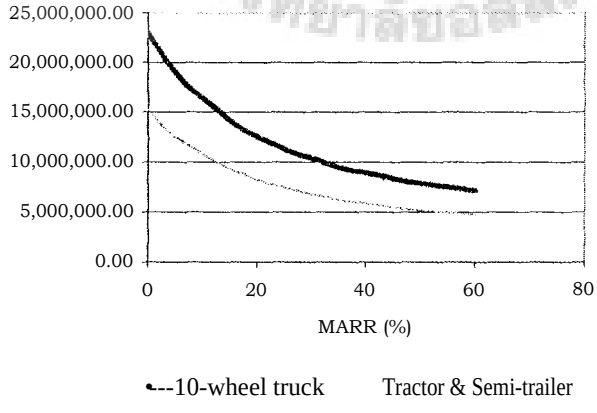


Figure 8.5. NPV at Any MARR (Bangkok-Phuket)

Table 9.5. NPV at Any MARR (Bangkok-Phuket)

MARR	10-wheel truck	Tractor & Semi-trailer
0	23,149,102.98	15 193,419.95
5	19,163,159.58	12,586 438.50
10	16,294,513.47	10,709,873.10
15	14,173,879.81	9,322,373.95
20	12,567,674.95	8,271,264.16
25	11,324,092.79	7,457,308.52
30	10,341,982.52	6,814,377.97
35	9,552,375.86	6,297,378.45
40	8,907,235.53	5,874,898.01
45	8,372,436.43	5,524,619.54
50	7,923,288.94	5,230,394.80
55	7,541,624.09	4,980,339.08
60	7,213,858.83	4,765,566.47

From figure 8.5, it shows that no interception point between 10-wheel truck line and tractor & semi-trailer line. The IRR of 10-wheel truck compared to tractor & semi-trailer cannot be calculated, but it show that at every MARR (minimum average rate of return), the 10-wheel truck's alternative total cost in NPV term will always more than the tractor & semi-trailer's total cost in NPV.

In this case, $NPVI_{10\text{-wheel truck}} > NPVsenu\text{-}trailer$, at MARR = 15%

$EUAW10\text{-wheel}_{truck} > EUAWsenu\text{-}tratler$, at MARR = 15%

Total cost of 10-wheel truck > Total cost of tractor & semi-trailer (at any MARR, from figure 8.5).

So, the tractor & semi-trailer alternative is more economical than the 10-wheel truck alternative.

LX. CONCLUSIONS AND RECCOMMEDATIONS

A. Conclusions

A Truck is one of the important types of vehicles in the transportation system, that is shown in this report. And this report shows that:

- The estimating cost method of TRRL can be applied to Thailand conditions. The factors that are necessary in analyzing operating cost of truck are: rise and fall of route, speed of truck, power to weight ratio, gross vehicle weight, roughness of route, commutative kilometres of vehicle, average annual kilometres, life time of vehicle, and vehicle price. These factors are used in calculating the operating cost of truck. The operating cost of truck consists of running cost: fuel consumption, lubricating oil consumption, vehicle maintenance parts consumption, vehicle maintenance labor hours, tire consumption, vehicle depreciation, and crew hours, and standing costs.
- The engineering economic method can be applied to use in analyzing the operating costs of each truck. The results can be used to be criteria in selecting the better alternative.
- The results from every case shows that tractor & semi-trailer is more economical than 10-wheel truck. The results can be shown as follows:
  - Bangkok-Chiengrai route.

	10-wheel truck	Tractor & semi-trailer
NPV	13 594,566.29	8,930,276.72
EUAW	2,849,067.84	1,871,553.95

- Bangkok-Ang Thong route.

	10-wheel truck	Tractor & semi-trailer
NPV	12,748,783.48	8,369,024.98
EUAW	2,671,813.74	1,753,930.17

— Bangkok -Khonkhean route.

	10-wheel truck	Tractor & semi-trailer
NPV	13,640,345.35	8,907,550.57
EUAW	2,858,661.94	1,866,791,14

- Bangkok-Khanchanaburi route.

	10-wheel truck	Tractor & semi-trailer
NPV	11,770,495.41	7,703,104.45
EUAW	2,466,789.98	1,614,370.53

- Bangkok-Phuket route.

	10-wheel truck	Tractor & semi-trailer
NPV	14,173,879.81	9,322,373.95
EUAW	2,970,476.90	1,953,727.34

B. Recommendations

- The results of this analysis may have some errors because of lack of data or - not enough data to use (no specified party to collect this data).
- Other routes in Thailand should be analyzed to obtain more results as reference data to transportation companies.

- These methods should be applied to other vehicles. It will be useful to the public.
- The estimating cost method of TRRL and the engineering economic method should be introduced to the public. It may be applied to other businesses.
- Although in this report the results state that tractor & semi-trailer is more economical than ten-wheel truck, the number of ten-wheel trucks in transportation businesses are more than tractor & semi-trailers. The causes of this are:-

The companies use ten- wheel trucks for a long time. If they change their trucks from ten-wheel trucks to tractor & semi-trailers, they must invest a lot of money.

Most roads in Thailand are not proper for big size trucks like tractor & semi-trailer. Such tractor & semi-trailer are hard to turn on roads because tractor & semi-trailer have a large turn around radius.

Tractor & semi-trailers cannot go into the small areas. In Thailand, there are a lot of small areas that must use the door-to-door transportation.

- In using tractor & semi-trailers, the goods stations are necessary for using as the center for distributing the goods but there are a few goods stations in Thailand. So, it is not proper to use tractor & semi-trailer.
- The initial cost of tractor & semi-trailer is higher than ten-wheel truck. This is the important point for a small company because the small company has not enough money to invest.
- The new skills training programs for drivers are necessary to be set if the transportation business will change from ten-wheel truck to tractor & semi-

trailers. It must use a lot of money to set these programs and no owner of companies can invest in them.

The structure of roads in Thailand cannot support the high loads. The big size trucks like tractor & semi-trailer are the cause of damage to road surfaces.

APPENDIX A

MAINTENANCE COSTS FROM MITSUBISHI MOTOR

MAINTENANCE COSTS FROM MITSUBISHI MOTOR

X 1,000	km.	5	10	15	20	25
1. ENGINE OIL	K64 FE FK	558 675 975	558 675 975	558	558 675 975	558
2. T/M OIL	K64 _PE FK	150 201 435			150 201 435	
3. D/F OIL	K64 FE FK	97 292 422			97 292 422	
4. BRAKE	K64 FE FK					
5. S_LEERING	K64 FE FK					
6. OIL FILTER	K64 FE FK	221 1,033 683	221		221 1,033 683	
7. FUEL FILTER	K64 FE FK					
8. AIR CLEANER	KM 1·E FK					
9. LABOR (250/H)	KM FE FK	125 375 475	125 775 1,050	125	775 950 1,100	125
10. TOTAL COST	K64 PE FK	1,151 2,576 2,990	904 1,450 2,025	683 0 0	1,801 3,151 3,615	683 0 0

X 1,000	km.	30	35	40	45	50
1. ENGINE OIL	K64 FE FK	558 675 975	558	558 675 975	558	558 675 975
2. T/M OIL	K64 FE FK			150 201 435		
3. DIF OIL	K64 PE FK			97 292 422		
4. BRAKE	K64 FE FK					150 150 150
5. STEERING	K64 FE FK					90 186 248
6. OIL FILTER	K64 FE FK	221		221 1,033 683		221
7. FUEL FILTER	K64 FE FK					309 451 230
8. AIR CLEANER	K64 FE FK					458 1,241 1,594
9. LABOR (250/H)	K64 FE FK	650 1,275 1,400	125	875 975 1,100	125	150 1,400 1,075
10. TOTAL COST	K64 FE FK	1,429 1,950 2,375	683 0 0	1,901 3,176 3,615	683 0 0	1,936 4,103 4,272

X 1,000	km.	55	60	65	70	75
1. ENGINE OIL	K64 FE FK	558	558 675 975	558	558 675 975	558
2. TIM OIL	K64 FE FK		150 201 435			
3. D/F OIL	K64 FE FK		97 292 422			
4. BRAKE	K64 FE FK					
5. STEERING	K64 FE FK					
6. OIL FILIER	K64 FE FK		221 1,033 683		221	
7. FUEL FIL IER	K64 FE FK					
8. AIR CLEANER	K64 FE FK					
9. LABOR (250/H)	K64 FE FK	125	800 1,225 3,825	125	150 775 1,050	125
10. TOTAL COST	K64 FE FK	683 0 0	1,826 3,426 6,340	683 0 0	929 1,450 2,025	683 0 0

X 1,000	km.	80	85	90	95	100
1. ENGINE OIL	K64 FE FK	558 675 975	558	558 675 975	558	558 675 975
2. T/M OIL	K64 FE FK	150 201 435				150 201 435
3. D/F OIL	K64 FE FK	97 292 422				97 292 422
4. BRAKE	K64 FE FK					150 150 150
5. STEERING	K64 FE FK					90 186 248
6. OIL FILTER	K64 1.'E. FK	221 1,033 683		221		221 1,033 683
7. FUEL FILTER	K64 FE FK					309 451 230
8. AIR CLEANER	K64 FE FK					458 1,241 1,594
9. LABOR (250/H)	K64 FE FK	900 975 1,100	125	150 1,450 1,600 '	125	1,225 1,500 1,125
10. TOTAL COST	K64 PE FK	1,926 3,176 3,615	683 0 0	929 2,125 2,575	683 0 0	3,258 5,729 5,862

APPENDIX B

DETAILS OF A 10-WHEEL TRUCK FROM MITSUBISHI MOTOR

DETAILS OF A 10-WHEEL TRUCK FROM MITSUBISHI MOTOR

MITSUBISHI FUSO FV SERIES

DETAIL			FV415.1M1Y.DITA	FV41511RIWIIB	FV4171412S1iIXIA	FV4171I12SI7DH13
SIZE WEIGHT	TOTAL LENG1TT	mm	7,280	6,750		
	TOTAL WIDTH	mm.	2,480			
	TOTAL HEIGHT	mm.	3,210	3,200	3,185	
	SPAN	mm.	4,510	4,350		
	Wheel width	Front	2,040		2,050	
		Rear mm.	1,845			
	Weight	Full load kg.	27,600	50,000		
		No load kg.	7,470		6,985	
	Turn over radius	м.	7.2	6.9		
	Gradient		27.5	16.5	20.5	
	Max. velocity	lot./h	89	104	101	
ENGINE	Model		8DC9-3A		6D24-0AT1	
			Diesel V8		Diesel V6	
	Cylinder Volume	cc.	16,031		11,945	
	Size x Stoke	mm.	135 x 140		130 x 150	
	Max. power; .11S		310 14P/2,200 Cycle per min.		320 HP/2,200 Cycle per min.	
	EEC kw/cycle/ min.		221/2,200		228/2,200	
	Max. torque EEC N-m/cycle/min.		1,005/1,400		1,201/1,400	
FUEL SYSTEM	Oil system		Direct injection			
	Oil tank	liters	200			

MITSUBISHI FUSO FV SERIES

DETAIL			FV415JMRUHA	FV415HRRDI113	FV417HRSRDHA	FV417FERSRDIID
TRANSMITTION SYSTEM	Clutch		Dry type			
	Gear system		6 Gear Forward	10 Gear Forward		
				HIGH		LOW
	Gear ratio	1 st	6.552	7.145		9.153
		2nd	4.178	3.733		4.783
		3rd	2.587	2.158		2.765
		4th	1.621	1.301		1.666
		5th	1.000	0.780		L000
		6 th	0.758	-		
		Backward	6.849	6.327		8.105
	Rear pinion ratio		6.666	5.571		
ELECTRIC SYSTEM	Battery		2 x 12 V/120 Amp.			
	Motor Start		24 V / 6.0 kW		24 V / 5.5 kW	
	Alternator		AC 24 V/40 Amp.	AC 24 V / 15 Amp.		
STEERING			Power Steering			
SUSPENSION SYSTEM	Front		Spring & Choke up			
	Rear		Spring			
BREAK SYSTEM			AIR OVER HYDRAULIC	2 FULL AIR SYSTEMS, SPRING LOAD (MAXI-BRAKE)		
TIRE	Front & rear		11.00-20-14 PR		10.00-20.14 PR	
SPECIAL PART	Power take off		Fly wheel PTO	Transmission PTO	-	Transmission PTO
	Cab & Seat		Cab suspension	Seat air suspension	Cab suspension	Seat air suspension

APPENDIX C

DATA FOR HEAVY TRUCKS

1. Fuel Consumption for Heavy Truck (Liters/1000km)

Average BHP = 150

RS = 0, F = 0

Average Velocity (km/h)	No load GVW=10 tons P/W=15:1	Half load GVW=15 tons P/W=10:1	Full load GVW=20 tons P/W=7.5:1	Overload GVW=25 tons P/W=6:1
10	255.4	324.8	378.2	423.5
20	209.2	278.4	332.0	377.3
30	202..3	269.5	323.1	368.4
40	203.3	272,3	325,9	371,2
50	212.5	281.7	335,3	380.6
60	226.9	296.1	349.7	395.0
70	245.5	314.7	368.3	413.6
80	267.9	337,1	390.7	436.0
90	293.9	363.1	416.7	426.0

RS= 10, F = 10

10	283.9	353,1	406,7	452,0
20	237.7	306.9	360.5	405.8
30	230.8	298.0	351.6	396.9
40	231.8	300.8	354.4	399.7
50	241.0	310,2	363,8	409,1
60	255.4	324.6	378,2	423.5

Average Velocity (km/h)	No load GVW=10 tons P/W=15: 1	Half load GVW=15 tons WW=10:1	Full load GVW=20 tons P/W=7.5:1	Overload GVW=25 tons P/W=6:1
70	274.0	343.2	396.8	442.1
80	296.4	365.6	419.2	464.5
90	322.4	391.8	445.2	490.5

RS = 20, F = 20

10	312.5	381.7	435.3	480.6
20	266.3	335.5	389.1	434.4
30	259.4	326.6	380.2	425.5
40	260.4	329,4	383.0	428.3
50	269.6	336,8	392.4	437.7
60	284.0	353.2	406.8	452.1
70	302.6	371.8	425.4	470.7
80	325.0	394.2	447,8	493.1
90	351.0	420.2	473.8	519.1

RS = 30, F = 30

10	341.1	410.3	463,9	509,2
20	294.9	364.1	417.7	463.0
30	288.0	355.2	408.8	454.1
40	289.0	358.0	411.6	456.9
50	298.2	367.4	421,0	466.3
60	312_6	381.8	435.4	480.7
70	331.2	400.4	454.0	499.3

Average Velocity (km/h)	No load GVW=10 tons P/W=15 :1	Half load GVW=15 tons P/W=1 0 : 1	Full load GVW=20 tons P/W=7.5 :1	Overload GVW=25 tons P/W=6 : I
80	353.6	422.8	476.4	521.7
90	379.6	488.8	502.4	547.7

RS = 40, F = 40

10	369,6	438.8	492.4	537,7
20	323.4	392.6	446.2	491.5
30	316.5	383.7	437.3	482.6
40	317.5	386.5	440.1	485.4
50	326,7	395,9	449,5	494.8
60	341.1	410.3	463.9	509.2
70	359.7	428.9	482.5	527.8
80	382.1	451.3	504.9	550.2
90	408.1	477,3	530,9	576,2

RS = 50, F = 50

10	398.2	467.4	521.0	566.3
20	352.0	421.2	474.8	520.1
30	345.1	412.3	465.9	511.2
40	346.1	415.1	468.7	514.0
50	355.3	424.5	478.1	523.4
60	369.7	438.9	492.5	537.8
70	388.3	457.5	511.1	556.4
80	410.7	479.9	533.5	578.5

Average Velocity (km/h)	No load GVW=10 tons P/W=15:1	Half load GVW=15 tons P/W=10:1	Full load GVW=20 tons P/W=7.5:1	Overload GVW=25 tons P/W=6:1
90	436.7	505.9	559,5	604.8

RS = 60, F = 60

10	426.8	496.0	549.6	594.9
20	380,6	449,8	503.4	548,7
30	373.7	440.9	494.5	539.8
40	374.7	443.7	497.3	542.6
50	383.9	453.1	506.7	552.0
60	398,3	467.5	521.1	566.4
70	416.9	486.1	539.7	585.0
80	439.3	508.5	562.1	607.4
90	465.3	534.5	588.1	633.4

RS = 70, F = 70

10	455.4	524.6	578.2	623.5
20	409.2	478.4	532.0	577.3
30	402.3	469.5	523.1	568.4
40	403.3	472.3	525.9	571.2
50	412.5	481.7	535.3	580.0
60	426.9	496.1	549.7	595.0
70	445.5	514.7	568.3	613,0
80	467.9	537.7	590.7	616.0
90	493.9	563.1	616.7	662.0

2. Parts Consumption for Heavy Truck

Distance 40,000 km/year

Life (years)	Commutative Distance (km)	Spare Part Cost (baht/1000 km)
1	40,000	0.458×10^{-3} VP
2	80,000	0.917×10^{-3} VP
3	120,000	1.375×10^{-3} VP
4	160,000	1.834×10^{-3} VP
5	200,000	2.292×10^{-3} VP
6	240,000	2.750×10^{-3} VP
7	280,000	3.209×10^{-3} VP
8	320,000	3.667×10^{-3} VP

Distance 50,000 km/year

Life (years)	Commutative Distance (km)	Spare Part Cost (baht/1000 km)
1	50,000	0.573×10^{-3} VP
2	100,000	1.146×10^{-3} VP
3	150,000	1.719×10^{-3} VP
4	200,000	2.292×10^{-3} VP
5	250,000	2.865×10^{-3} VP
6	300,000	3.438×10^{-3} VP
7	350,000	4.011×10^{-3} VP
8	400,000	4.584×10^{-3} VP

Distance 60,000 km/year

Life (years)	Commutative Distance (km)	Spare Part Cost (baht/1000 km)
1	60,000	0.688×10^{-3} VP
2	120,000	1.375×10^{-3} VP
3	180,000	2.063×10^{-3} VP
4	240,000	2.750×10^{-3} VP
5	300,000	3.438×10^{-3} VP
6	360,000	4.126×10^{-3} VP
7	420,000	4.813×10^{-3} VP
8	480,000	5.501×10^{-3} VP

Distance 70,000 km/year

Life (years)	Commutative Distance (km)	Spare Part Cost (baht/1000 krn)
1	70,000	0.802×10^{-3} VP
2	140,000	1.604×10^{-3} VP
3	210,000	2.407×10^{-3} VP
4	280,000	3.209×10^{-3} VP
5	350,000	4.011×10^{3} VP
6	420,000	4.813×10^{-3} VP
7	490,000	5.615×10^{-3} VP
8	560,000	6.418×10^{-3} VP

Distance 80,000 kin/year

Life (years)	Commutative Distance (km)	Spare Part Cost (baht/1000 km)
1	80,000	0.917×10^{-3} VP
2	160,000	0.834×10^{-3} VP
3	240,000	2.750×10^{-3} VP
4	320,000	3.667×10^{-3} VP
5	400,000	4.584×10^{-3} VP
6	480,000	5.501×10^{-3} VP
7	560,000	6.418×10^{-3} VP
8	640,000	7.334×10^{-3} VP

3. Maintenance Labor Cost for Heavy Truck

Distance 40,000 km/year

Life (years)	Commutative Distance (km)	Labor Hour (h/1000 km)
1	40,000	1.30
2	80,000	2.60
3	120,000	3.90
4	160,000	5.20
5	200,000	6,50
6	240,000	7.80
7	280,000	9.10
8	320,000	10.39

Distance 50,000 km/year

Life (years)	Commutative Distance (km)	Labor Hour (h/1000 km)
1	50,000	1.62
2	100,000	3.25
3	150,000	4.87
4	200,000	6.50
5	250,000	8.12
6	300,000	9.75
7	350,000	11.37
8	400,000	12.99

Distance 60,000 km/year

Life (years)	Commutative Distance (km)	Labor Hour (h/1000 km)
1	60,000	1.95
2	120,000	3.90
3	180,000	5,85
4	240,000	7.80
5	300,000	9.75
6	360,000	11.70
7	420,000	13,64
8	480,000	15.59

Distance 70,000 km/year

Life (years)	Commutative Distance (km)	Labor Hour (h/1000 km)
1	70,000	2.27
2	140,000	4.55
3	210,000	6.82
4	280,000	9.10
5	350,000	11.37
6	420,000	13.64
7	490,000	15.92
8	560,000	18.19

Distance 80,000 km/year

Life (years)	Commutative Distance (km)	Labor Hour (h/1000 km)
1	80,000	2.60
2	160,000	5.20
3	240,000	7.80
4	320,000	10.39
5	400,000	12.99
6	480,000	15.59
7	560,000	18.19
8	640,000	20.79

4. Depreciation Calculation for Heavy Truck

Year	DP (% of VP)
1	31%
2	16.3%
3	11.4%
4	9.1%
5	7.7%
6	6.7%
7	6.0%
8	5A%
9	0

5. Crew Hours

$$\text{Crew Hours per km} = \frac{\text{Average annual crew hours}}{K_A}$$

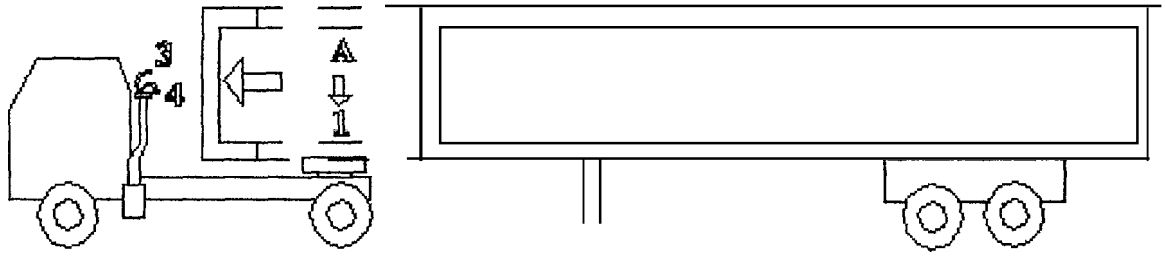
Annual kilometer per year (K_A)	Average annual crew hours (h/year)	Average crew hours per 1,000 km (h/1,000 km)
50,000	5,072	101.44
60,000	5,072	84.53
70,000	5,072	72.46
80,000	5,072	6140

6. Tire Consumption for Heavy Truck

No Load	(GVW = 10 tons)—	0,1032	unit/1,000 km
Half Load	(GVW = 15 tons)—	0.1547	unit/1,000 km
Full Load	(GVW = 20 tons)—	0.2063	unit/1,000 km
Overload	(GVW = 25 tons)—	0.2579	unit/1,000 km

APPENDIX D

EQUIPMENT DESCRIPTION OF A TRACTOR TRAILER



C 5Th Wheel (Coupler)

Coupling device mounted on the semi-trailer tractor is coupling king pin of the trailer, 5th wheel is divided into two classes according to their functions, single-axle and two-axle 5th wheel.

- Single-axle 5th wheel

Single-axle 5th wheel is provided only with the pitching shaft and functions in accordance with tractor and trailer movement. In this case rolling movements are absorbed by the rear suspension spring on the tractor Q. Load supported by 5th wheel is called 5th wheel load.

- Two-axle 5th wheel

Two-axle 5th wheel is comprises the pitching shaft and rolling shaft. By operating these shafts, relative pitching and rolling movements between the tractor and the trailer are absorbed_

© King Pin

Coupling device attached to the semi-trailer and coupled to the tractor 5tj wheel so that the trailer can be hauled. The dimensions of the king pin vary according to load, that is, 2" or 31/2" diameter king pin can be selected_

© Jumper Cable

Electric wiring of the tractor and the trailer is performed by jumper cables and couplings. A plug at the end of the cable is to be inserted into the socket of the trailer. Coupling system is based on the SAE standards.

0 Jumper Hose

Brake piping is performed by jumper hose and couplings. Jumper hoses comprise a pair of hose for service brake and emergency brake. A coupling is attached to the one of jumper hose. Coupling system is based on the SAE standards.

© Landing Gear

Landing gear is a stand for supporting trailer so that it may not tilt when separated from the tractor.

© Relay Emergency Valve

Relay emergency valve functions normally like relay valve. Should the trailer be separated from the tractor while running the valve operates the emergency brake to step the trailer.

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