Implement control:

The tractor with a built in lift system is connected to the implement through a specific type of mechanical linkage termed as three point linkage and the system is known as mounted system. The implement is connected to the tractor hydraulic system at two bottom links and one top link. Both the bottom links are connected to two lift arms through lift links. The lift arms are directly mounted on a rock shaft which is further connected to the piston rod. Any movement of the piston is transferred to the bottom links. The top link is used for connecting the third hitch point of the implement and is adjustable for maintaining the implement level and suction angle. Load sensing for the draft control can also be done through the top link which is spring loaded. In some tractors the lower links are spring loaded for draft sensing.

Depending upon the soil condition and type of operation the mounted implement can be controlled either by position control or draft control.

Weight transfer:

Rear part of the tractor is heavier than the front part to get higher tractive efficiency. However, sufficient weight on the front axles is also required to facilitate easy steering and to compensate the effect due to weight transfer. When the load is pulled, the tendency of front axle is to become light by losing some weight and the same adds to the rear axle.

The higher the pull, the greater is the weight transfer. Mathematically this can be represented by:

Weight transfer= pull× hitch height/ wheel base.

Where the line of pull is always assumed to be parallel to the ground.

Power take off unit (PTO):

It is a part of tractor transmission system. It consists of a shaft, a shield and a cover. The shaft is externally splined to transmit torsional power to another machine. A rigid guard fitted on a tractor covers the power take off shaft as a safety device. This guard is called power take off shield. Agricultural machines are coupled with this shaft at the rear part of the tractor. As per ASAE standard PTO speed is 540± 10 rpm when operating under load. In order to operate 1000rpm PTO drive machine, a new standard has been developed.

Traction:

A pneumatic tyre which is flexible has a smaller contact area on cocreate surface than it dose on soft ground. A rule of thumb which can be used for estimation of tire contact area is given below-

$$A = bl$$

Where:

A = Tire contact area

b = Section width of tire

l = Contact length of tire

experimentally it has found that it is

A = 0.78 bl

Traction testing machine

The traction testing device, is a soil bin based that can be used to conduct controlled experiments.. With this tires of varying diameters widths can be tested. The system is designed will provide variable vertical load up to get varying pull force. The device can be operated in a draft control or a slip control mode.The simplest device for a traction test of a wheeled device requires supporting the moving wheel, which applythe required torque, and measuring the developed force . However, there are variousways by which this can be carried out , with varying levels of complexity. Some devices can be operated only in soilbins, whereas, others are operated in the field.

Tire testing procedure

The tire test consisted of several runs and for a given run, vertical load on the tire is varied to get pull force under controlled slip using load cell type of sensors. The slip control mode may include zero slip to higher slip levels using single wheel tyre tester. In this type of machine torque and speed can also be measured by installing the required sensors to estimate traction performance parameters.

Traction Terminology

Traction.

The process by which a tractor develops tractive force and overcomes motion resistance to produce desired motion.

Tractive force

The force developed on the tractor interface by the traction device as a result of applied torque from the power source.

Motion resistance

Any force imposing resistance against desired motion.

Rolling resistance

Motion resistance that arises from deformations in the soil and the traction device

Sinkage

The depth to which the traction device penetrate into the soil measurednormal to the original, undisturbed surface.

Slip

It is an indication of how the speed of the traction device differs from the forward speed of the tractor. It can be defined as as the percentage travel reduction and given as

$S = [1 – Va/Vt] 100$

Coff

Traction efficiency

The efficiency of the tractive device is converting the axle input power into output power, the term tractive efficiency (TE) has been defined as

TE = Output power/ Input power x100

Basically tractive efficiency is converting the axle torque into net traction .

Traction prediction equation

Dimensional analysis is the best technique used to develop the prediction models for traction forces of pneumatic wheel type of tractor in tillage operation. Soil-wheel interaction was considered in developing the prediction models. Based on the Buckingham Pi Theorem, the number of dimensionless and independent quantities required to fully express the relationship between the variables were determined. Total number of factors can be listed as below table1-

Table 1 : the effective factors of soil and tractor

Effective factors	Definition	Symbol	Unit	MLT
Soil engineering properties	Cone index	CI	N/m^2	$ML^{-1}T^{-2}$
Tractor parameters	Tyre breadth	B	m	M^0LT^0
	Tyre diameter	D	m	M^0LT^0
	Tyre rolling radius	R	m	M^0LT^0
	Tractor weight	W	N	MLT^{-2}
Operational parameters	Tractive force	F	N	MLT^{-2}
	Towed force	F_T	N	MLT^{-2}
	Pull	F_P	N	MLT^{-2}
	Slip	S	-	

The factors listed above in table 1, can be written as-

$F, F_T, F_P = f(CI, B, D, R, W, S)$

According to Buckingham's theory, the number of invariants and repetitive invariants were 9 and 2 respectively, so 7 constant pi-values are obtained. In this, two repetitive invariants - weight (W) and breadth(B) are used. Using the dimensional analysis with considering the two repeating variables, the π numbers can be written as –

$\Pi_1, \Pi_2, \Pi_3 = f(\Pi_4, \Pi_5, \Pi_6 \Pi_7)$

Equating the exponents of two sides of each π number and by Solving these we obtained an equations for a1, b1, …, , with seven dimensionless parameters in the form as mentioned below-

$\Pi_1 = F(W)^{a1}(B)^{b1} = M^0L^0T^0$

$\Pi_2 = F_T(W)^{a2}(B)^{b2} = M^0L^0T^0$

$\Pi_3 = F_P(W)^{a3}(B)^{b3} = M^0L^0T^0$

$\Pi_4 = CI(W)^{a4}(B)^{b4} = M^0L^0T^0$

$\Pi_5 = D\,(W)^{a5}(B)^{b5} = M^0L^0T^0$

$\Pi_6 = R(W)^{a6}(B)^{b6} = M^0L^0T^0$

$\Pi_7 = S(W)^{a7}(B)^{b7} = M^0L^0T^0$

The combination of extracted π numbers can be written as a functional equation in the form of:

$\Pi_{1,} = F/W$

$\Pi_{2,} = F_T/W$

$\Pi_3 = F_P/W$

$\Pi_4 = B^2CI/W$

$\Pi_5 = D/B$

$\Pi_6 = R/B$

$\Pi_7 = S$

It can also be written as –

$F/W, F_T/W, F_P/W = B *D* CI/W, D/B, R/B, S$

TOWED WHEEL

A towed wheel is an unpowered wheel and axle torque is considered to be zero . The towed force of a towed pneumatic tire is generally dependent upon load, size and inflation pressure, as well as soil strength. Hence the towed force can be predicted from-

$F_T/W = 1.2/Cn + 0.o4$

Where

F_T = towed force of wheel

W= dynamic wheel load

B = unloaded tire width

D = unloaded tire diameter.

Cn= wheel numeric

$Cn = B\ D\ CI/W$

CI = cone index

DRIVING WHEEL

The variations of driving wheel performance is based on the consideration that the normal tire inflation pressures in agricultural tyres produce tire deflections of approximately 20 per cent. Therefore, traction prediction equation can be given as for net pull, slip, and load -

$F_P /W = 0.75(1- e^{-CnS}) - (1.2/Cn + 0.04)$

Where,

F_P = wheel pull

W = dynamic wheel load

e = base of natural logarithms

$Cn = CIBD/W$

CI, B,D and S as stated before.