OPTIMAL FLEET ALLOCATION TO DISTRIBUTION CENTERS

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OBJECTIVE.

- distribution of a limited, homogeneous, preexisting and usually scarce amount of vehicles to a set of distribution centers (DCs).

  - Seeks optimal economical yield
  - through the most efficient fleet allocation

Contribution Margin.

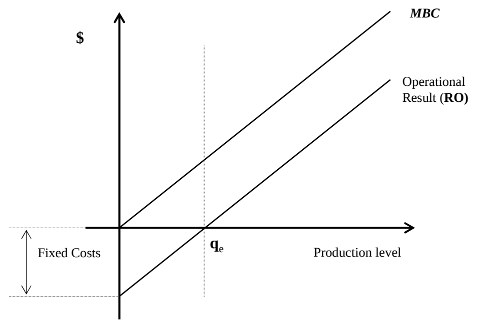
- The Key Performance Indicator.

$$mc = pv - cv$$

$$MBC = R - CV$$

- (mc) unitary contribution margin
- (pv) unitary sales price
- (cv) unitary variable cost
- (MBC) gross contribution margin
- (RB) gross income
- (CV) total variable cost

Contribution Margin Concepts



- Good Linearity to the problem

BASIC FORMULATION.

- maximize

$$MBC = \sum_{i=1}^{n} MC_i . x_i$$

where

x_i is the integer number of vehicles allocated to distribution center ***i***,

MC_i is the contribution margin that one vehicle yields in ***DC i***,

MBC is the gross contribution margin for the whole considered system

n is the number of distribution centers involved in the fleet's rearrangement.

BASIC FORMULATION.

- Vehicle productivity may vary from one ***DC*** to another,
- MC_i may be expressed by

where

$$MC_i = p_i . mc_i$$

p_i represents the productivity of a generic vehicle at DC_i and

mc_i the unitary contribution margin at the same ***DC***.

- Costs involved in redistributing the vehicles must also be taken into account.

AN INITIAL TWO - STEPS METHOD

- a linear integer programming model followed by a transportation problem model,
- may not bring to the optimal solution on situations where:
  - **Costs of sending vehicles between DCs is significantly high** (e.g.: DCs are located too far away from each other).
  - **The present fleet distribution is too close to optimal**; therefore, again, the gain in the gross contribution margin is not sufficiently high in order to supplant de fleet's redistributing costs.
  - **The redistributing cost matrix between DCs is not symmetrical**, causing this two step procedure to ignore some of the possible solutions.

INTEGRATED MODEL.

- maximize

$$RTORF = \sum_{i=1}^{n}\sum_{j=1}^{n}(p_j.mc_j - p_i.mc_i - c_{ij}).x_{ij}$$

subject to $\sum_{j=1}^{n} x_{ij} = b_i$ $\qquad \sum_{i=1}^{n} x_{ij} \le a_j = \left\lceil D_j / p_j \right\rceil$

$$\sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij} = X \qquad \sum_{i=1}^{n} x_{ij} \ge q_{\min j}$$

$$x_{ij} \ge 0$$

INTEGRATED MODEL.

where

the decision variables ***xij*** represent the number of vehicles to be sent from the origin DC_i to the destiny DC_j,

- p_i and p_j are the productivity figures achieved by a generic vehicle respectively at ***DCs i*** and ***j***,
- mc_i and mc_j are de unitary contribution margins at ***DCs i*** and ***j***, respectively,
- c_{ij} is the cost of relocating one vehicle from DC_i to DC_j and

RTORF is the performance indicator representing the total gain achieved with the fleet's redistribution operation (Resultado Total da Operação de Remanejamento da Frota, in Portuguese). and....

INTEGRATED MODEL.

...and

- a_j is the maximum allowable quantity of vehicles that can be sent to DC_j from all DC_i,
- D_j is the estimated market demand at DC_j,
- b_i is the vehicle availability at DC_i,
- ***X*** is the total amount of vehicles in the fleet and
- $q_{min\ j}$ is the minimum allowable number of vehicles to be allocated at DC_j.

PRACTICAL APLICATION.

- Real data from a ready-mix concrete operation.
  - minimum and maximum amount of vehicles to be allocated;
  - next planning period forecasts including:
    - contribution margin,
    - vehicle productivity and,
    - market demand in volume; and
  - present situation concerning both;
    - fleet distribution and...
- Distances between each two cities where the plants are located.

PRACTICAL APLICATION.

Table I - SUPPLIED DATA FROM A READY-MIX OPERATION.

Batching Plant	i	Vehicle limits: minimum	Vehicle limits: maximum	Following Month's Forecasts: mc (R$/m³)	Following Month's Forecasts: p (m³/veic. mês)	Following Month's Forecasts: Demand D (m³/mês)	Present Situation: Vehicle quantity	Present Situation: MBC(R$)
São Paulo	1	0	59	21,00	335	20.000	46	323.610
Santos	2	0	12	55,00	360	4.350	10	198.000
Campinas	3	0	13	28,00	340	4.550	12	114.240
Ribeirão Preto	4	0	10	29,00	445	4.700	11	141.955
Sorocaba	5	2	12	15,00	270	3.350	10	40.500
S. J. Campos	6	0	9	30,00	330	3.150	9	89.100
Rio de Janeiro	7	0	12	39,00	295	3.650	11	126.555
Belo Horizonte	8	0	11	28,00	350	4.000	11	107.800
Curitiba	9	0	25	27,00	370	9.550	23	229.770
Londrina	10	0	19	31,00	350	6.650	19	206.150
Florianópolis	11	14	19	20,00	310	6.000	12	74.400
Blumenau	12	0	11	33,00	235	2.700	11	85.305
Porto Alegre	13	0	11	26,00	360	4.200	10	93.600
			223	23,83	334,6	76.850	195	1.830.985

PRACTICAL APLICATION.

Table of Distance Between Plants (km)														
		São Paulo	Santos	Campinas	Rib. Preto	Sorocaba	S.J.Campc	R.Janeiro	Bel.Horiz.	Curitiba	Curitiba	Floripa.	Blumenau	P. Alegre
	i/j	1	2	3	4	5	6	7	8	9	10	11	12	13
São Paulo	1	-	72	99	319	87	97	429	586	408	528	528	656	1.109
Santos	2	72	-	171	391	159	169	501	658	480	600	777	728	1.181
Campinas	3	99	171	-	238	85	174	511	601	476	526	773	724	1.177
Ribeirão Preto	4	319	391	238	-	324	408	725	324	681	478	848	939	1.342
Sorocaba	5	87	159	85	324	-	180	512	674	391	451	688	890	1.092
S. J. Campos	6	97	169	174	408	180	-	343	611	515	621	807	758	1.216
Rio de Janeiro	7	429	501	511	725	512	343	-	434	852	953	1.144	1.096	1.553
Belo Horizonte	8	586	658	601	324	674	611	434	-	1.004	1.002	1.301	1.252	1.712
Curitiba	9	408	480	476	681	391	515	852	1.004	-	379	300	251	711
Londrina	10	528	600	526	478	451	621	953	1.002	379	-	686	637	1.040
Florianópolis	11	705	777	773	848	688	807	1.144	1.301	300	686	-	139	476
Blumenau	12	656	728	724	939	890	758	1.096	1.252	251	637	139	-	599
Porto Alegre	13	1.109	1.181	1.177	1.342	1.092	1.216	1.553	1.712	711	1.040	476	599	-

- Distances between plants.

PRACTICAL APLICATION.

Table III - COST OF VEHICLE DISPATCH BETWEEN PLANTS.														
		São Paulo	Santos	Campinas	Rib. Preto	Sorocaba	S.J.Campc	R.Janeiro	Bel.Horiz.	Curitiba	Londrina	Floripa.	Blumenau	P. Alegre
	i/j	1	2	3	4	5	6	7	8	9	10	11	12	13
São Paulo	1	-	30	42	158	37	41	204	270	195	246	246	354	568
Santos	2	30	-	72	188	67	71	234	354	226	330	404	384	598
Campinas	3	42	72	-	100	36	73	239	330	224	245	403	382	596
Ribeirão Preto	4	158	188	100	-	160	195	383	160	364	225	434	496	720
Sorocaba	5	37	67	36	160	-	76	239	361	188	213	367	452	561
S. J. Campos	6	41	71	73	195	76	-	168	335	240	339	417	396	667
Rio de Janeiro	7	204	234	239	383	239	168	-	206	436	502	582	562	832
Belo Horizonte	8	270	354	330	160	361	335	206	-	524	523	702	682	899
Curitiba	9	195	226	224	364	188	240	436	524	-	183	150	105	377
Londrina	#	246	330	245	225	213	339	502	523	183	-	366	346	539
Florianópolis	11	374	404	403	434	367	417	582	702	150	366	-	58	224
Blumenau	#	354	384	382	496	452	396	562	682	105	346	58	-	276
Porto Alegre	#	568	598	596	720	561	667	832	899	377	539	224	276	-

- Costs of vehicle dispatch between plants.

OPTIMAL SOLUTION.

Table IV - OPTIMAL SOLUTION FOR THE READY-MIX CONCRETE FLEET REDISTRIBUTION

GAIN RTORF = R$ 55.140		DESTINATIONS													
	i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	Availability
ORIGINS	1	43	-	-	-	-	-	-	-	-	-	3	-	-	46
	2	-	10	-	-	-	-	-	-	-	-	-	-	-	10
	3	-	-	12	-	-	-	-	-	-	-	-	-	-	12
	4	-	-	1	10	-	-	-	-	-	-	-	-	-	11
	5	3	2	-	-	2	-	1	-	2	-	-	-	-	10
	6	-	-	-	-	-	9	-	-	-	-	-	-	-	9
	7	-	-	-	-	-	-	11	-	-	-	-	-	-	11
	8	-	-	-	-	-	-	-	11	-	-	-	-	-	11
	9	-	-	-	-	-	-	-	-	23	-	-	-	-	23
	10	-	-	-	-	-	-	-	-	-	19	-	-	-	19
	11	-	-	-	-	-	-	-	-	-	-	11	-	1	12
	12	-	-	-	-	-	-	-	-	-	-	-	11	-	11
	13	-	-	-	-	-	-	-	-	-	-	-	-	10	10
DEMANDS	MAXIMUM	59	12	13	10	12	9	12	11	25	19	19	11	11	223
	USED	46	12	13	10	2	9	12	11	25	19	14	11	11	195
	MINIMUM	-	-	-	-	2	-	-	-	-	-	14	-	-	
INITIAL STATUS		46	10	12	11	10	9	11	11	23	19	12	11	10	195
DIFFERENCE		0	2	1	-1	-8	0	1	0	2	0	2	0	1	0

OPTIMAL SOLUTION.

Table V - ACHIEVED BENEFITS

	Gross Contribution Margin MBC (R$)	Fixed Costs CF (R$)	Operational Result OR (R$)	Delivery Capacity (m^3)	Productivity (m^3/month)
Initial	1,830,985	1,450,000	380,985.	65,815.	337.5
Optimized	1,886,125	1,450,000	436,125.	66,285.	339.9
Diference	55,140.	-	55,140	470.	2.4
% gain/loss	3.0%.	-	14.5%.	0.7%.	0.7%