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# An Application of Multi Objective Programming Techniques: A Case Study of South India (Andhra Pradesh, Karnataka)

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***Abstract: In India and abroad, the commonly used decision modeling in real life rests on the assumption that the decision maker seeks to optimize a well-defined single objective using traditional mathematics programming approach. A farmer may be interested in maximizing his cash income, with certain emphasis on risk minimization. On the other at county level especially in a developing country a planner may aspire for a plan while maximizes food grains production and also to some extent considers employment maximization etc as the goals. Keeping in view the objectives of the study, state-wise secondary data on different variables for the period 1980-81 to 2014-15 were collected from Statistical Abstracts of Punjab, Fertilizer Statistics, Agricultural Statistics at a glance and the reports of the Commission for Agricultural Costs and Prices, published by Ministry of Agriculture By taking its deviations of observed Yt from its estimated value we got the error or the risk coefficients for each year for each crop. These risk coefficients were taken in the matrix formulation in the MOTAD format suggested by Hazell (1971 a and b). To give a meaningful explanation to the level of risk, total mean absolute deviations in gross returns were derived as under: Min A = 1/S Σ│ (chj-gj) xj│ Where A is the minimum average absolute deviation defined as the mean over (h=1………s) years, of the sum of the deviations of gross returns (chj) from the trend in gross returns (gj) multiplied by activity levels x j (j = 1………n). Where A is an unbiased estimator of the population mean absolute income deviation Where A = estimated mean absolute deviation S = no. of years chj = gross returns of the jth activity in hth year gj = sample mean of gross returns of jth activity x j = activity level This was minimized subject to the following constraints: Σaij xj ≤ bi (for all i = 1………….m, j =1……..n) Total activity requirements for the i th constraint, the sum of the unit activity requirements aij for the constraint i times the activity levels 'xj'do not exceed the level of the i th constraint bi for all 'i' and x j 0 all activity levels are non negative. Where a ij = per unit technical requirement for the jth activity of the ith resourcebi = the ith resource constraint level m = no. of constraints n = no. of activities.***

***Keywords: Multi Objective Linear Programming Techniques.***

## I. INTRODUCTION

In India and abroad, the commonly used decision modeling in real life rests on the assumption that the decision maker seeks to optimize a well-defined single objective using traditional mathematical programming approach. Usually taking farming as a business enterprise, a centrist farmer will always like to allocate all the resources available at his farm in such a way that he may get maximum possible income. However in reality this is not the case as the decision maker is usually seeking an optimal compromise amongst several objectives, many of which may be in conflict. For example a farmer may be interested in maximizing his cash income, with certain emphasis on risk minimization. On the other at county level especially in a developing country a planner may aspire for a plan while maximizes food grains production and also to some extent considers employment maximization etc as the goals. So in the real world the decision makers are engaged in pursuit of several objectives and the traditional paradigm is in fact inadequate for dealing with such situations.

The application of multiple objective planning techniques in farm planning will undoubtedly lend realism to the exercise in farm planning because of the great potential of multiple objective programming in handling farm planning problems more comprehensively and its acceptability for developing the optimum farm plan is being increasingly recognized . The traditional mathematical programming approach to the modeling of agricultural decisions rests on certain basic assumptions about the situation being modeled and the decision maker himself. One fundamental assumption is that the decision maker (DM) seeks to

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optimize a well defined single objective. In reality this is not the case, as the DM is usually seeking an optimal compromise amongst several objectives, many of which can be in conflict, or trying to achieve satisfying levels of his goals. For instance, a subsistence farmer may be interested in securing adequate food supplies for the family, maximizing cash income, increasing leisure, avoiding risk etc. but not necessarily in that order. Similarly a commercial farmer may wish to maximize gross margin, minimize his indebtedness, acquire more land, reduce fixed costs etc. Two main types of decision-making situations are identified. The first situation deals with problems involving a single decision criterion or objective, while the second one involves several conflicting objectives. It is argued that decision makers are in reality engaged in the pursuit of several objectives and the traditional paradigm is inadequate for dealing with such situations. The present study is undertaken to analyze the food grain production and resource use and to suggest optimum production plans at existing technology for Punjab and Haryana. More specifically the objective of the study is to develop the optimum production plans

## II. REVIEW OF LITERATURE

Pant and Pandey (1999) made attempt to delineate the major environmental protection objectives for the hill agriculture, and to develop a multi-objective farm planning model for minimisation of environmental problems while maintaining the present level of foodgrain production and farm income. For the purpose, a representative hill district of Dhanding in Nepal was selected for obtaining the requisite data and other information. In all optimal plans, negative deviations from the economic goal levels (i.e. Targets for food grains production, milk production and cash farm income) and positive deviations from environmental goal levels (i.e. targets for soil erosion, cattle grazing, forest fodder and use of nitrogen, phosphorus and pesticides) are minimized. The optimum plan also suggests the substitutions of buffaloes for cows for milk production compared to the cows, the buffaloes have higher milk productivity, with more percentage of fat in milk. Provided, yet they did not seem to be adequately utilized by the villagers.

Malhan (1996) generated the compromise farm plans for different farm size categories for different zones in the Punjab state considering different objectives i.e. maximization of cash income and labour employment, minimization of working capital borrowing and labour use variability and also minimization of risk by using multi-objective programming techniques. he suggested different compromise farm plans on different farm situations which were preferred than the existing plan of each objective.

Domingo and Rehman (1988) presented an approach synthesizing MOTAD methods with in a compromise programming model to generate 'best compromise' solution which come closest to an ideal point. This approach can be regarded as compromise risk programming method (CRP). The objectives considered were minimizing the sum of absolute values of the total gross margin deviation and maximizing the expected gross margins.

## III. RESEARCH METHODOLOGY

Keeping in view the objectives of the study, state-wise secondary data on different variables for the period 1980-81 to 2014-15 were collected from Fertilizer Statistics, Agricultural Statistics at a glance and the reports of the Commission for Agricultural Costs and Prices, published by Ministry of Agriculture, By taking its deviations of observed $Y_t$ from its estimated value we got the error or the risk coefficients for each year for each crop. These risk coefficients were taken in the matrix formulation in the MOTAD format suggested by Hazell (1971 a and b). To give a meaningful explanation to the level of risk, total mean absolute deviations in gross returns were derived as under:

$\text{Min } A = 1/S\ \Sigma \left| (ch_j - g_j)\, x_j \right|$

Where A is the minimum average absolute deviation defined as the mean over (h=1………s) years, of the sum of the deviations of gross returns ($ch_j$) from the trend in gross returns ($g_j$) multiplied by activity levels $x_j$ (j = 1………n). Where A is an unbiased estimator of the population mean absolute income deviation

Where A = estimated mean absolute deviation

S = no. of years

$ch_j$ = gross returns of the jth activity in hth year

$g_j$ = sample mean of gross returns of jth activity

$x_j$ = activity level

This was minimized subject to the following constraints:

$\Sigma a_{ij}\, x_j \le b_i$ (for all i = 1………….m, j =1……..n)

Total activity requirements for the $i_{th}$ constraint, the sum of the unit activity requirements $a_{ij}$ for the constraint i times the activity levels '$x_j$'do not exceed the level of the $i_{th}$ constraint bi for all 'i' and $x_j$ 0 all activity levels are non negative.

Where $a_{ij}$ = per unit technical requirement for the jth activity of the ith resource.

$b_i$ = the $i_{th}$ resource constraint level

m = no. of constraints

n = no. of activities

## IV. RESULT AND DISCUSSION

### ANDHRA PARDESH

In table 1 the elements of the first four rows and columns forms the pay off matrix for the Andhra Pradesh pure the ideal production plan representing maximum possible returns of 112.09 million Rs. (31.72 percent charges) a maximum possible production 26.10 (33.58 percent charges) million tons of food grains, maximum of man power employment 610.9 (29.78 percent charges) million man days and the minimum possible risk in returns (mean absolute deviation) 9.78 (13.02 percent declining) billion Rs. Under the present resource constraints were possible employing resources optimally. The table also shows the anti-ideal plan for gross returns 78.17 billion Rs. under the ideal plan for risk. Similarly anti-ideal 17.88 million tons of grain production, 472.6 million days of labour use. The anti-ideal point for risk was Rs. 14.37 million under the maximum grain production plan.

By optimizing gross returns or by giving 100 percent weight to this objective we get the elements of first row of the pay off matrix. Here the optimum farm plan I shows the increase in gross returns by 31.72 percent, grain production 33.18 percent, labour use 27.27 percent and in risk 27.64 percent as compare to existing level by following the increase in paddy area by 21.03 percent and maize are by 53.43 percent as compare to existing level while Bajra enter at minimum level in irrigated conditions. In the rabi season, rabi rabi rice was the most profitable crop which shows 22.57 percent increase, while wheat shows 16.18 percent decline as compare to existing level. Under un-irrigated conditions paddy being the most profitable kharif crop followed by maize and mash which showed an increase of area by 233.33 percent, 61.50 percent and 62.35 percent respectively. While Tur shows the decline in area by 6.26 percent. Jowar, Bajra and moong shows no charges. In rabi season, rabi rice and wheat showed an increase of 211.10 percent and 1.15 percent respectively being the most profitable rabi crop, while gram shows the decline in area by 59.18 percent as compare to existing level. The row 2nd of pay off matrix indicating the maximum optimum of grain production at 26.10 million tons of grain production which gave the same plan as plan-I under irrigated conditions which shows that the crops whose yield were high were also the most remunerative crops. Under un-irrigated conditions, in Khariff season the area under Jowar was increased by 44.35 percent while area under mash was decreased by 7.37 percent as compare to existing level. The optimum plan 3 suggests that a maximum of 610.9 million days of human labour employment can the achieved showing the 29.8 percent increase in employment as compare to exiting labour use by following the form plan I and II under irrigated conditions indicating that labour intensive crops were also the most remunerative/ high grain yielding crops. Under un-irrigated conditions area under Jowar increased by 72.35 percent while area under maize decreased by 23.39 percent. The fourth plan of the table shows the plan under least possible risk, it entailed a minimum risk of 9.78 million Rs. In growing the rabi and kharif crops at their minimum level for example under irrigated conditions paddy, wheat, paddy (Rabi) Bajra and Maize entered at 1987, 1321, 863, 16, 101 thousand hectare level and under un-irrigated conditions paddy, paddy (Rabi), wheat Jowar, bajra, maize, gram, tur, moong and Mash entering at 95, 36, 513, 789, 80, 203, 60, 299, 455 and 465 thousand hectare level.

The resource use pattern in pay off matrix shows (table .2) that consumption of kharif fertilizer would increase by 46.33 percent, 50.44 percent, 49.66 percent and 7.10 percent in plan I, II, III and IV respectively and rabi fertilizer would be increased by 11.37 percent in plan-I, II and III while a decline of 17.78 percent in plan IV as compare to existing level. The khraif and rabi capital would be increased by 44.27 percent, 44.91 percent, 44.67 percent and 8.94 percent in plan I, II, III and IV and 8.71 percent in plan I, II and III while decline of 18.26 percent in plan IV respectively. The labour requirement increased by 27.27 percent, 29.36 percent, 29.78 percent and 0.40 percent in form plan I, II, III and IV as compare to existing labour use

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**TABLE 1: PAY OFF MATRIX AND CROPPING PATTERN FOR THE FOUR OBJECTIVES FOR ANDHRA PRADESH, 2014- 15**

Note: Figure in parentheses represents percentage change over existing level

| THE OBJECTIVES & THEIR CORRESPONDING VALUES | | | | | AREA UNDER FOOD GRAINS (000 HECTARE) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | IRRIGATED | | | | | UNIRRIGATED | | | | | | | | | |
| **Variables** | **Gross Returns (billion Rs.)** | **Production (Million Tons)** | **Human labour (Million days)** | **Risk (Billion Rs.)** | **Paddy Kharif** | **Wheat** | **Paddy Rabi** | **Bajra** | **Maize** | **Paddy Kharif** | **Paddy Rabi** | **Wheat** | **Jowar** | **Bajra** | **Maize** | **Gram** | **Tur** | **Moong** | **Mash** |
| Existing pattern | 85.10 | 19.53 | 470.7 | 11.24 | 2287 | 1576 | 1072 | 16 | 131 | 96 | 45 | 612 | 789 | 80 | 265 | 147 | 319 | 455 | 502 |
| Gross Returns (billion Rs.) | 112.09 (31.72) | 26.024 (33.18) | 599.1 (27.27) | 14.35 (27.64) | 2768 (21.03) | 1321 (-16.1) | 1314 (22.57) | 16 (0.0) | 201 (53.43) | 320 (233.3) | 140 (211.1) | 668 (9.15) | 789 (0.0) | 80 (0.0) | 428 (61.50) | 60 (-59.1) | 299 (-6.2) | 455 (0.0) | 815 (62.35) |
| Production (Million Tons) | 111.53 (31.05) | 26.10 (33.58) | 608.9 (29.36) | 14.37 (27.79) | 2768 (21.03) | 1321 (-16.1) | 1314 (22.57) | 16 (0.0) | 201 (53.43) | 320 (233.3) | 140 (211.1) | 668 (9.15) | 1139 (44.35) | 80 (0.0) | 428 (61.50) | 60 (-59.1) | 299 (-6.2) | 455 (0.0) | 465 (-7.37) |
| Human labour (Million days) | 110.34 (29.66) | 25.68 (31.45) | 610.9 (29.78) | 13.97 (24.22) | 2768 (21.03) | 1321 (-16.1) | 1314 (22.57) | 16 (0.0) | 201 (53.43) | 320 (233.3) | 140 (211.1) | 668 (9.15) | 1364 (72.35) | 80 (0.0) | 203 (-23.3) | 60 (-59.1) | 299 (-6.2) | 455 (0.0) | 465 (-7.37) |
| Risk (Billion Rs.) | 78.17 (-8.14) | 17.88 (-8.45) | 472.6 (0.40) | 9.78 (-13.0) | 1987 (-13.1) | 1321 (-16.1) | 863 (-19.4) | 16 (0.0) | 101 (-22.9) | 95 (-1.04) | 36 (-20.0) | 513 (-16.1) | 789 (0.0) | 80 (0.0) | 203 (-23.3) | 60 (-59.1) | 299 (-6.2) | 455 (0.0) | 465 (-7.37) |

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**TABLE-2 RESOURCE USE PATTERN IN PAY OF MATRIX FOR THE FOUR OBJECTIVES FOR ANDHRA PRADESH, 2014-15**

| PARTICULARS | EXISTING USE | PLANS | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| **Kharif fertilizer (000 tons)** | 315.189 | 461.24 (46.33) | 474.19 (50.44) | 471.715 (49.66) | 337.58 (7.10) |
| **Rabi fertilizer (000 tons)** | 237.097 | 264.072 (11.37) | 264.072 (11.37) | 264.072 (11.37) | 194.922 (-17.78) |
| **Kharif Capital (billion Rs.)** | 24.014 | 34.65 (44.27) | 34.801 (44.91) | 34.743 (44.67) | 26.17 (8.99) |
| **Rabi capital (billion Rs.)** | 19.53 | 21.233 (8.71) | 21.233 (8.71) | 21.233 (8.71) | 15.96 (-18.26) |
| **Total human labour (million man days)** | 470.7 | 599.1 (27.27) | 608.9 (29.26) | 610.9 (29.78) | 427.6 (0.40) |

Note: Figure in parentheses represents percentage change over existing level.

**KARNATAKA**

In table 3 the elements of the first four rows and columns form the pay off matrix for the Karnataka. Here the ideal production plan representing maximum possible returns 41.92 billion Rs. A maximum possible grain production 9.90 million tons, maximum of man power employment 342.0 million man days and minimum possible risk in returns (mean absolute deviation) 4.25 billion Rs. under the present resource optimally. The table also shows the anti-ideal plan for gross returns 27.61 billion as under the ideal plan for risk. Similarly anti-ideal 6.30 million tons of grain production, 282.6 million days of labour use. The anti-ideal point for risk was 7.34 billion Rs. Under the maximum human labour employment plan.

By optimizing gross returns or by giving 100 percent weight to this objective we get the dements of first row of the pay off matrix. Here the optimum farm plan I shows the increase in gross returns by 36.4 percent, in grain production 35.53 percent, in labour use 23.84 percent and in risk 18.13 percent as compare to existing level by following the increase in paddy area by 37.07 percent while decline in maize area by 55.13 percent as compare to existing level under irrigated conditions. Jowar and Bajra entered in the plan at the minimum level. This shows that the paddy was the most profitable cultivated kharif crop in Karnataka. In the rabi season the most profitable crop was gram which shows the 76.6 percent increase, while wheat shows 25.74 percent decline as compare to existing level. Under unirrigated conditions paddy being the most profitable crop showed an increase of 29.15 percent, while maize and tur shows the increment of 29.29 percent and 17.17 percent. The area under moong and mash shows the decline in area by 33.72 percent and 34.69 percent respectively. In rabi season under unirrigated conditions, wheat showed an increase of 127.4 percent, Rabi rice showed on increasing of 46.27 percent and gram 38.23 percent, as compare to the existing level, being the most profitable rabi crops. Which enters at the maximum level. The row 2$^{nd}$ of pay off matrix indicating the maximum optimum of grain production at 9.90 million tons of grain production (shows the 36.45 percent increase as compare to existing level) by following the same Khraif plan as plan I under irrigated conditions and in rabi season wheat showing the 9.90 percent increase while gram showing the 43.3 percent decline in area as compare to existing pattern which indicating the wheat is more yielding crop under irrigated conditions. Under unirrigated land, in kharif season Bajra crop shows the increment of 75.5 percent while tur shows the decline in area by 28.43 percent. In rabi season the area, under wheat increased by 279.8 percent while area under gram decreased by 43.46 percent. The optimum plan 3 suggests that a maximum of 342.0 million days of human labour employment can be achieved showing the 27.23 percent increase in employment as compare to existing labour use by following the farm plan II under irrigated conditions indicating that labor intensive crops were also high grain yielding crops. Under un-irrigated land, area under Tur increased by 77.01 percent while maize showed 54.8 percent decline in area. The fourth plan of the table shows the plan under least possible risk, it entailed a minimum risk of Rs. 4.252 billion in growing rabi and kharif crops at their minimum level for example under irrigated conditions paddy, wheat, jowar, bajra, maize and gram entering at 474, 75, 113, 35, 118 and 17 thousand hectare level and under unirrigated conditions paddy (kharif), paddy (rabi), wheat, jowar, bajra, maize, gram, tur, moong and mash entering at 102, 197, 164, 1784, 258, 134, 173, 302, 169 and 96 thousand hectare level.

The resource use pattern in pay off matrix shows (table 4.) that consumption of kharif fertilizer would increased by 37.66 percent, 40.17 percent, 38.47 percent and 1.49 percent in plan I, II, III and IV respectively while the consumption of rabi fertilizer would be increased by 53.01 percent in plan I and 8399 percent in plan II, III and 66.91 percent in plan IV as compare to existing resource use pattern. The use of kharif capital will be increased by 28.75 percent, 29.44 percent, 26.73 percent and declined by (-

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0.62 percent) in plan I, II, III and IV respectively while rabi capital shows the increment of 49.80 percent in plan I, 56.00 percent in plan II, III and 21.89 percent in Plan IV. The labour requirement increased by 23.84 percent, 25.00 percent, 27.23 percent and 5.13 percent in optimizing plan I, II, III and IV respectively as compare to existing labour use.

**Karnataka:**

**TABLE 3: PAY OFF MATRIX AND CROPPING PATTERN FOR THE FOUR OBJECTIVES FOR KARNATAKA, 2014-15**

| THE OBJECTIVES & THEIR CORRESPONDING VALUES | | | | | AREA UNDER FOOD GRAINS (000 HECTARE) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | IRRIGATED | | | | | | UNIRRIGATED | | | | | | | | | |
| **Variables** | **Gross Returns (billion Rs.)** | **Production (Million Tons)** | **Human labour (Million days)** | **Risk (Billion Rs.)** | **Paddy** | **Wheat** | **Jowar** | **Bajra** | **Maize** | **Gram** | **Paddy Kharif** | **Paddy Rabi** | **Wheat** | **Jowar** | **Bajra** | **Maize** | **Gram** | **Tur** | **Moong** | mash |
| **Existing pattern** | 30.81 | 7.25 | 268.8 | 5.82 | 712 | 101 | 113 | 35 | 263 | 30 | 319 | 322 | 164 | 1784 | 258 | 297 | 306 | 422 | 255 | 147 |
| **Gross Returns (billion Rs.)** | 41.92 (36.04) | 9.83 (35.53) | 332.9 (23.84) | 6.87 (18.13) | 976 (37.07) | 75 (-25.7) | 113 (0.0) | 35 (0.0) | 118 (-55.1) | 53 (76.6) | 412 (29.15) | 471 (46.2) | 373 (127.4) | 1784 (0.0) | 258 (0.0) | 384 (29.29) | 423 (38.23) | 497 (17.77) | 169 (-33.7) | 96 (-34.6) |
| **Production (Million Tons)** | 41.40 (34.35) | 9.90 (36.45) | 336.0 (25.0) | 6.69 (15.02) | 976 (37.07) | 111 (9.90) | 113 (0.0) | 35 (0.0) | 118 (-55.1) | 17 (-43.0) | 412 (29.15) | 471 (46.2) | 623 (279.8) | 1784 (0.0) | 453 (75.5) | 384 (29.2) | 173 (43.4) | 302 (28.4) | 169 (33.7) | 96 (-34.6) |
| **Human labour (Million days)** | 40.92 (32.80) | 9.45 (30.27) | 342.0 (27.23) | 7.34 (26.12) | 976 (37.07) | 111 (9.90) | 113 (0.0) | 35 (0.0) | 118 (-55.1) | 17 (-43.3) | 412 (29.15) | 471 (46.2) | 623 (279.8) | 1784 (0.0) | 258 (0.0) | 134 (-54.8) | 173 (-43.4) | 747 (77.01) | 169 (-33.7) | 96 (-34.6) |
| **Risk (Billion Rs.)** | 27.61 (-10.4) | 6.30 (-13.1) | 282.6 (5.13) | 4.25 (-26.9) | 474 (-33.4) | 75 (-25.7) | 113 (0.0) | 35 (0.0) | 118 (-55.1) | 17 (-43.3) | 102 (-68.2) | 197 (-38.8) | 164 (0.0) | 1784 (0.0) | 258 (0.0) | 134 (-54.8) | 173 (-43.4) | 302 (-28.4) | 169 (-33.7) | 96 (-34.6) |

Note : Figure in parentheses represents percentage change over existing level.

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**TABLE 4. RESOURCE USE PATTERN IN PAY OF MATRIX FOR THE FOUR OBJECTIVES FOR KARNATAKA, 2014-15**

| PARTICULARS | EXISTING USE | PLANS | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| **Kharif fertilizer (000 tons)** | 155.919 | 214.653 (37.66) | 218.553 (40.17) | 215.903 (38.47) | 158.243 (1.49) |
| **Rabi fertilizer (000 tons)** | 34.39 | 52.634 (53.01) | 63.288 (83.99) | 63.288 (83.99) | 571.4 (66.91) |
| **Kharif Capital (billion Rs.)** | 19.703 | 25.368 (28.75) | 22.505 (29.44) | 24.971 (26.73) | 19.580 (-0.62) |
| **Rabi capital (billion Rs.)** | 3.371 | 5.050 (49.80) | 5.259 (56.00) | 5.259 (56.00) | 4.109 (21.89) |
| **Total human labour (million man days)** | 268.8 | 332.9 (23.84) | 336.0 (25.00) | 342.0 (27.23) | 282.6 (5.13) |

Note : Figure in parentheses represents percentage change over existing level.

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