Identification and Appraisal of Rural Roads Projects

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IDENTIFICATION AND APPRAISAL OF RURAL ROADS PROJECTS

This paper describes an operational approach to the identification and appraisal of projects consisting of rural roads and complementary investments. The objective for such projects is to prepare and implement a comprehensive, multi-sectoral development program on the basis of rural roads in their zones of influence. The methodology can, therefore, also be applied to rural development projects.

The principal purpose of the identification process is to ascertain the development potential of a rural road's zone of influence. In many instances this may depend on the potential of one or two crops, which, therefore, should be examined with more care. The appraisal methodology determines the appropriate scope and timing for road improvements or construction, their maintenance needs, and the complementary investments in other sectors, without which (in most cases) the road improvements or construction would not be justified. In other words, the project attempts to achieve an optimal development package for each road's zone of influence. The linkages between agricultural and transport components are emphasized.

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ANNEX

1. Economic Analysis of Road and Agricultural Investments
IDENTIFICATION AND APPRAISAL
OF RURAL ROADS PROJECTS

I. INTRODUCTION

1. The Bank's experience indicates that, to achieve optimal benefits, it is frequently necessary to integrate road improvements and agricultural development; the main reason for not achieving forecast economic returns (ERs) of road improvements in the past is the absence of a complementary agricultural development program. Thus rural road improvements often cannot be expected to raise agricultural production automatically. Vice versa, rural development projects often require a rural roads component to complement investments in agricultural production in order that the project achieve its full development impact. The approach calls, therefore, for improvements of rural roads and complementary agricultural investments.

2. The main features of the approach to project preparation are: (i) focus on individual rural roads and their specific zones of influence; (ii) the development of an integrated investment package for each road's zone of influence; and (iii) the integration of these investment packages into regional and national development plans.

3. Investment packages may consist of: (i) rural road improvements; (ii) equipment for improved rural road maintenance; (iii) land clearing, planting of permanent crops, purchase of cattle, equipment and tool procurement, and development of on-farm storage, which require on-farm investments by participating farmers; (iv) inputs such as fertilizers, seeds, labor and renting of equipment which require incremental working capital; (v) improved extension services; and (vi) collection facilities, equipment maintenance and rental facilities, etc. Recommendations with regard to the inclusion of certain or all components in the investment package are based on an
analysis of the potential agricultural development and traffic requirements in each rural road's zone of influence.

4. The purpose of this paper is to describe an Identification Method and a Rural Roads Program\(^1\) which have been primarily developed to test alternative agricultural and road development strategies and to determine ERs and net present values (NPVs) of the aforementioned investment packages. It does not deal with at least equally important matters such as the organization necessary for successful implementation of a rural roads project, the preparation of extension manuals and action programs indicating the responsibilities of each concerned agency, indicators required to follow the implementation of each component of the investment packages, and the development of appropriate management information and monitoring systems. The Rural Roads Program may be used for the appraisal of rural roads projects as well as the appraisal of rural development projects.

5. In order to obtain a balanced and optimal investment package, the development of integrated investment packages is not only recommended for those roads whose improvement could not be justified without complementary agricultural investments, but also for those roads where road user savings alone would warrant improvement. The availability of investment packages for each road makes it possible, from the outset, to identify key crops and actions to be taken for successful project implementation. As a result, available extension and other support services can be focussed from the start on these crops and actions and their effectiveness should therefore be considerably improved.

6. The zones of influence of the rural roads are determined by: (i) the rural road network around the road being analyzed; (ii) the distances

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\(^1\) A detailed methodology for appraising investment packages of rural roads and complementary agricultural investments.
between farms and local markets; (iii) the terrain; and (iv) the means of transport used such as pack animals, animal-drawn carts, agricultural tractors, pickups, trucks, passenger cars, and buses.

7. In most situations benefits resulting from complementary agricultural investments and investments for rural road improvements do not accrue to final consumers of agricultural products since these investments are normally not large enough to affect retail prices significantly. Benefits stemming from agricultural investments accrue primarily to farmers, while those from road improvements may accrue to farmers and/or transporters.

8. Ignoring transport savings resulting from an improved rural road which accrue to non-agricultural traffic, the benefits (B) to be had in a specific year from an investment package of a rural road improvement and complementary investments for one agricultural crop in its zone of influence are:

\[
B = \left[ \text{value added of incremental agricultural production} \right] - \left[ \text{incremental costs of production and transportation to local markets} \right] + \left[ \text{loss in consumer surplus} \right]
\]

Annex 1 shows that

\[
B = P_m (q_2 - q_1) - (R_2 - R_1) - P_1(H_1 - H_2) - \frac{1}{2}(H_1 - H_2)(P_2 - P_1)
\]

where:

\[
P_m = \text{local market price of a specific agricultural product (tons)}
\]

\[
q_1, q_2 = \text{exports of this product from road's zone of influence in the without- and with-project situation, respectively (tons)}
\]

\[
R_1, R_2 = \text{total economic cost of producing and transporting this product to the local market, in the without- and with-project situation, respectively ($)}
\]

\[
P_1, P_2 = \text{farm-gate price of this product in the without- and with-project situation, respectively ($/ton)}
\]

1/ Section IV describes a situation with potential benefits accruing to farmers, transporters and final consumers.
\( H_1, H_2 \) = home or on-farm consumption of this product in the without- and with-project situation, respectively (tons)

The above-mentioned prices are efficiency prices. Assuming that salvage values are negligible, expression (1) may be used to estimate the benefits of any year during the expected life of the investment project. This expression can also be applied to each crop of a zone of influence, if there is more than one crop cultivated; the benefits are, in this situation, obtained by addition of the benefits related to each crop.

9. The last two terms of expression (1) represent the potential home consumption loss due to larger exports in the with-project situation. The term \( \frac{1}{2} (H_1 - H_2)(P_2 - P_1) \) is negligible if the farm-gate price elasticity of the agricultural product considered, and the difference between \( H_1 \) and \( H_2 \) are small. Note that the local market price \( P_m \) of expression (1) is assumed to remain constant in the without- and with-project situations, and therefore the benefits accruing to final consumers are zero (para. 7).

10. Annex 1 also shows that expression (1) can be rewritten as

\[ B = B_1 + B_2 \]

where

\[ B_1 = \text{benefits accruing to farmers} \]
\[ B_2 = \text{benefits accruing to transporters} \]

or

\[ B_1 = P_2 q_2 - P_1 q_1 + P_1 (H_1 - H_2) - \frac{1}{2} (H_1 - H_2)(P_2 - P_1) - (C_2 - C_1) \]

\[ .............. \ (2) \]

and

\[ B_2 = P_2 q_2 - P_1 q_1 - (k_2 q_2 - k_1 q_1) \]

\[ .............. \ (3) \]

where \( P_2, P_1, q_2, q_1, H_1, H_2 \) are as defined in para. 8, and

\[ C_1, C_2 = \text{economic cost of producing the entire agricultural product under consideration in the without- and with-project situation, respectively} \ (4) \]
Either expression (1) or expressions (2) and (3) may be used for the identification and evaluation of an investment package. The choice between these expressions is a matter of convenience and depends on which required data are more easily available. The important point is not to use expression (1) with expression (3) which would lead to double counting. This paper employs expressions (2) and (3).

The ER and NPV of an investment package are computed by comparing total benefits, including transport savings accruing to non-agricultural traffic (para. 8), with total costs of road construction and maintenance and complementary agricultural investments. The computations become involved and cumbersome if there are more than three different agricultural outputs with more than three inputs in a zone of influence, even if all farms were of the same size so that differences in agricultural technologies and yields could be ignored. To handle these more complex project situations, a computer program called the Rural Roads Computer Program (RRCP) has been developed in order to facilitate the computations and sensitivity analyses. With the exception of the establishment of a link between agricultural yields and inputs, the RRCP does not determine links, such as those existing between higher farm income and additional transport, additional consumption and lower prices of agricultural products. These links have to be determined separately by the analyst as an input for the RRCP.

To further explain the methodology of the Identification Method and the Rural Roads Program, Section II, A Simple Example, describes the
evaluation of an over simplified case, i.e., one typical farm size, with only two crops in a rural road's zone of influence. Section III describes the Identification Method for rural roads projects. This method is based upon the results of sensitivity testing of ERs and NPVs obtained during the appraisal of about 60 individual rural roads and complementary agricultural investments in the zones of influence of these roads in Tunisia. The principles underlying the Identification Method and those underlying the appraisal method (i.e., the Rural Roads Program) are the same. The difference between these two methodologies is that a number of simplifications has been introduced in the Identification Method. These simplifications consist of the elimination of a number of input data which facilitates the computations. With the hope that it will prove useful for other project analysts, Section IV presents the analytical framework of the Rural Roads Program, which is the logical basis of the RRCP. The RRCP has several unique features that distinguish it from other programs available or under preparation for the analysis of rural development/roads projects. These features include a road network analysis; links between savings in transportation costs and farm-gate prices, traffic, and production; a generalized determination of the optimal investment year; an aggregation of benefits by beneficiary groups, etc.
II. A SIMPLE EXAMPLE

14. The purpose of this example is to illustrate the practical steps necessary for identifying and appraising an investment package consisting of a rural road and complementary agricultural investments. The number of outputs, inputs, agricultural investments, farm sizes and transport means is kept to a minimum in order to facilitate the presentation. Following a brief description of the project components and data requirements (paras. 15 - 22) a step-by-step analysis is given.

15. A hypothetical 30 km rural road in flat terrain has been selected for analysis. Improvement of the road from earth to all-weather gravel standard is proposed. The principal economic activity in the road's zone of influence (para. 6) is the production of wheat and tomatoes for export from this zone and for on-farm consumption. Most of the population of about 60,000 inhabitants in the zone of influence are farmers who own small lots of land. Population growth is estimated at 2.5% per year. It is assumed that the farms are all of the same size while used technologies and yields are also the same in a specific project situation.

16. The wheat and tomatoes are transported from the area by small trucks and mules plus carts. Passenger transportation is by land-rover. Traffic on the road averages four trucks, five carts and 4 land-rovers per day. Non-agricultural traffic other than these land-rovers (general freight, through traffic) is negligible. Average daily traffic by land-rover, which is assumed to be constant without road improvements, is estimated to grow at 5% per annum after the road improvement. Improvement of the rural road is not expected to generate or divert other traffic in the area.
17. The proposed investment package consists of:

(a) Road improvement ........ costs $1.20 million

(b) Wells and pumps ........... costs $0.20 million

(c) Extension services ...... costs $0.05 million.

The expected economic lives of all of these investments are, for simplicity reasons, assumed to be ten years while salvage values are negligible. In addition, it is assumed that these investments will be implemented over a period of two years. Consequently, improvements in agricultural yields, and savings in vehicle operating costs do not occur during these two years.

18. Annual road maintenance expenditures, which are negligible in the without-project situation, and annual agricultural production costs (labor, equipment, fertilizers, water, etc.) in the without- and with-project situations are given in Table II.1.

<table>
<thead>
<tr>
<th>Year</th>
<th>Road Maintenance Costs in With Situation ($'000)</th>
<th>Agricultural Production Costs per Ha ($)</th>
<th>Without Situation</th>
<th>With Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Wheat (3)</td>
<td>Tomatoes (4)</td>
<td>Wheat (5)</td>
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<tr>
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<td>0</td>
<td>80</td>
<td>520</td>
<td>90</td>
</tr>
<tr>
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<td>0</td>
<td>80</td>
<td>520</td>
<td>90</td>
</tr>
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</tr>
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<td>11</td>
<td>25</td>
<td>80</td>
<td>520</td>
<td>90</td>
</tr>
<tr>
<td>12</td>
<td>25</td>
<td>80</td>
<td>520</td>
<td>90</td>
</tr>
</tbody>
</table>

19. The crop area breakdown in the road's zone of influence and yields in the without- and with-project situations are given in the table below.
Table II.2: Crop Area Breakdown and Yields

<table>
<thead>
<tr>
<th></th>
<th>Wheat</th>
<th></th>
<th>Tomatoes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W/O Areas</td>
<td>W/O With</td>
<td>W/O Areas</td>
<td>W/O With</td>
</tr>
<tr>
<td>Year</td>
<td>('000 ha)</td>
<td>Unimproved</td>
<td>('000 ha)</td>
<td>Unimproved</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>1</td>
<td>5.0</td>
<td>5.0</td>
<td>0.0</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>5.0</td>
<td>5.0</td>
<td>0.0</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>5.0</td>
<td>4.0</td>
<td>1.0</td>
<td>0.6</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>4</td>
<td>5.0</td>
<td>3.0</td>
<td>2.0</td>
<td>0.6</td>
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<td>5.0</td>
<td>1.0</td>
<td>4.0</td>
<td>0.6</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>6</td>
<td>5.0</td>
<td>0.5</td>
<td>4.5</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>7</td>
<td>5.0</td>
<td>0.5</td>
<td>4.5</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>8</td>
<td>5.0</td>
<td>0.5</td>
<td>4.5</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>9</td>
<td>5.0</td>
<td>0.5</td>
<td>4.5</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>10</td>
<td>5.0</td>
<td>0.5</td>
<td>4.5</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>11</td>
<td>5.0</td>
<td>0.5</td>
<td>4.5</td>
<td>0.6</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>12</td>
<td>5.0</td>
<td>0.5</td>
<td>4.5</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

The with-project situation distinguishes unimproved cultivated areas, i.e., areas where techniques (and yields) remain as in the the without-project situation, and improved cultivated areas. This distinction reflects the farmers' adoption of new techniques advocated under the extension services of the with-project situation.

20. The per-ton farm-gate prices of local consumption and exports from the zone of influence are assumed to be the same in order to facilitate the presentation. They amount to $150 and $60 in the without-project situation and $155 and $65 in the with-project situation for wheat and tomatoes, respectively. The on-farm per-capita consumption of wheat and tomatoes in the without-project situation is 15 kg and 0.5 kg, respectively; corresponding values for the with-project situation are 12 kg and 0.3 kg.
21. Without- and with-project average fares and economic costs for transporting agricultural products over the 30 km road are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Without</th>
<th>With</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average fare ($/ton)</td>
<td>0.36</td>
<td>0.20</td>
</tr>
<tr>
<td>Average cost ($/ton)</td>
<td>0.29</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Note that:

(i) the per ton-km transport savings amount to $0.29-$0.11 or $0.18;
(ii) the transporters' per ton-km profit increases from $0.07 in the without-project situation to $0.09 in the with-project situation, or an increase of $0.02;
(iii) the difference between the aforementioned $0.18 and $0.02 or $0.16 which equals the difference between average fares of the without- and with-project situations, accrues to farmers;
(iv) the aforementioned $0.16 multiplied by the average road trip of 30 km equals $5.00 (rounded off), which is the amount by which the without-project farm-gate prices are increased in the with-project situation (para. 20); and
(v) the above fares and farm-gate prices imply that final consumers' prices in the market are assumed to remain constant in the without-and with-project situations.

The average fares and costs for transporting agricultural products are based on vehicle operating costs of small trucks and mules plus carts (para. 16); the with-project figures are lower due to savings in operating costs and the partial substitution of small trucks for mules plus carts.

22. The without- and with-project average vehicle operating costs of land-rovers on the 30 km rural road amount to $0.70 and $0.40, per vehicle-km, respectively.
23. The step-by-step analysis consist of:

(a) the establishment of benefits accruing to farmers [expression (2) of para. 10];

(b) the determination of benefits accruing to transporters [expression (3) of para. 10];

(c) the computation of transport savings related to non-agricultural traffic; and

(d) the determination of the ER and NPV of the investment package.

The annual wheat and tomatoe production, home (on-farm) consumption and exports as well as annual agricultural production costs are first determined, since they are required to establish the benefits accruing to farmers.

24. Annual wheat and tomatoe production. In the without-project situation, this production is obtained by multiplying the number of hectares shown in Column (2) of Table II.2 by the yield of Column (5) of this table. For instance, in year 3 the production of wheat is 5,000 ha times 0.6 ton/ha or 3,000 tons, which is reported in Column (3) of Table II.3. In the with-project situation, the agricultural production is obtained by taking the sum of (i) number of unimproved hectares in Column (3) of Table II.2 times the unimproved yield of Column (5) of this table, and (ii) number of improved hectares in Column (4) of Table II.2 times the improved yield of Column (6) of this table. For instance, in year 5 the production of wheat is 1,000 ha times 0.6 ton/ha plus 4,000 ha times 1.0 ton/ha, or 4,600 tons as shown in Column (4) of Table II.3.
<table>
<thead>
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</thead>
<tbody>
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<td>1</td>
<td>60.00</td>
<td>3.00</td>
<td>3.00</td>
<td>0.90 0.90</td>
<td>2.10 2.10</td>
<td>5.00 5.00</td>
<td>0.03 0.03</td>
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<td>4.97</td>
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<td>2</td>
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<td>3.00</td>
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<td>4.60</td>
<td>1.02 0.81</td>
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<td>5.00 10.00</td>
<td>0.03 0.02</td>
<td>4.97</td>
<td>9.98</td>
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<td>3.00</td>
<td>4.80</td>
<td>1.04 0.83</td>
<td>1.96 3.97</td>
<td>5.00 10.00</td>
<td>0.03 0.02</td>
<td>4.97</td>
<td>9.98</td>
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25. **Home consumption.** To determine this consumption, the population in the road's zone of influence during the time of implementation and expected life of the project, is first determined. Column (2) of Table II.3 reports these population statistics which are based on the base population of 60,000 and the 2.5% growth rate (para. 15). The annual home consumption of wheat and tomatoes is obtained by multiplying the corresponding annual population statistic by the on-farm per-capita consumption of wheat and tomatoes, respectively (para. 20). Columns (5), (6), (11) and (12) of Table II.3 show the aforementioned consumption.

26. **Annual exportable surplus.** The exportable surplus [Columns (7), (8), (13) and (14) of Table II.3] in the without- and with-project situation is obtained by deducting the corresponding home consumption from the production in the without- and without-project situation, respectively.

27. **Annual value of wheat and tomatoe exports.** In the without- and with-project situations these values are determined by multiplying the exports from the zone of influence by the corresponding farm-gate price (para. 20). For instance, in year 3 of the without-project situation, the value of the wheat exports is 2,050 [Column (7), Table II.3] times $150/ton, or $308,000. In year 5 of the with-project situation the value of wheat exports is 3,790 tons [Column (8), Table II.3] times $155/ton, or about $58,700. The export values are shown in Columns (2), (3), (9) and (10) of Table II.4.

28. **Annual costs of wheat and tomatoe production.** These costs are obtained by total number hectares times costs per ha. For instance, in year 3 of the without-project situation the costs of wheat production are 5,000 ha [Column (2), Table II.2] times $80/ha [Column (3), Table II.1], or $400,000 as shown in Column (5) of Table II.4. The costs of wheat production in the same year of the with-project situation amount to 4,000 ha [Column (3),
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Table II.2] times $80/ha [Column (3), Table II.1] plus 1,000 ha [Column (4), Table II.2] times $90/ha [Column (5), Table II.1], or $410,000 as shown in Column (6) of Table II.3. The annual costs of tomatoe production are shown in Column (12) and (13) of Table II.4.

29. **Annual net incremental values.** Columns (4) and (11) of Table II.4 show the net incremental values of the annual exports of wheat and those of tomatoes, respectively. These values are the differences between the export values in the with and those in the without-project situation. The net incremental production costs [Column (7) and (14) of Table II.4] are obtained in a similar manner. For instance, the net incremental production costs of tomatoes in year 5 is $275,000 [Column (13), Table II.4] minus $260,000 [Column (12), Table II.4] or $15,000 [Column (14), Table II.4].

30. **Home consumption loss.** This loss is determined by

\[ P_1 (H_1 - H_2) - \frac{1}{2} (H_1 - H_2)(P_2 - P_1) \]

of expression (2) of para. 10. The second term is not computed, since its value is negligible. Columns (8) and (15) of Table II.4 present the loss of home consumption of wheat and tomatoes. The loss of home consumption of wheat in, for instance, year 5 is determined by multiplying $150 (para.20) by the difference between the fifth-year values of Columns (6) and (5) of Table II.3 or 150(210) or $31,500.

31. Note that in Table II.4:

(i) Columns (2) and (9) correspond to the term \( P_1 q_1 \) of expression (2) of para. 10;

(ii) Columns (3) and (10) correspond to the term \( P_2 q_2 \) of this expression;

(iii) Columns (4) and (11) correspond to \( (P_2 q_2 - P_1 q_1) \) of this expression;

(iv) Columns (5) and (12) correspond to the term \( C_1 \) of this expression;
(v) Columns (6) and (13) correspond to the term $C_2$ of this expression; 
(vi) Columns (7) and (14) correspond to $(C_2 - C_1)$ of this expression; and 
(vii) Columns (8) and (15) correspond to $P_1(H_1 - H_2)$ of this expression.

32. **Annual agricultural transport fares and costs.** In the without-(with-) project situation the (i) annual agricultural transport fares and (ii) costs and obtained by (i) the product of the average transport fare per unit in the without- (with-) project situation (para. 21) times the distance of the road times the exportable surplus in the without- (with-) project situation [Columns (7) and (13) or Columns (8) and (14) of Table II.3] and (ii) the product of the average transport cost per unit (para. 21) in the without- (with-) project situation times distance of the road times the exportable surplus in the without- (with-) project situation. For instance, the fare for transporting wheat in the fifth year of the with-project situation amounts to

$0.20/\text{ton-km} \times 30 \text{ km} \times 3,790 \text{ tons}$, or about $22,740

as shown in Column (3) of Table II.5. The economic cost for transporting wheat in the third year of the without-project situation is

$0.29/\text{ton-km} \times 30 \text{ km} \times 2,050 \text{ tons}$, or about $17,840

as shown in Column (4) of Table II.5. Cost savings on transported agricultural inputs are negligible in this example; hence similar computations related to the transport of these inputs are not necessary.

33. **Transporters benefits.** These benefits are the difference between the transporters' profit in the with-project situation and their profit in the without-project situation. In other words, these benefits equal the fare in the with-project situation, minus the fare in the without-project situation minus the cost in the with-project situation plus the cost in the without-project situation. The transporters' benefits related to the transport of wheat and tomatoes are given in Columns (6) and (11) of Table II.5, respectively. Note that in Table II.5:
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Table II.6: Aggregation of Net Costs and Benefits Streams ($'000)

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Note: The table presents the aggregation of net costs and benefits streams over the specified years, with columns representing different cost and benefit categories.
36. It should be emphasized that the above example is based on a number of simplifying assumptions, including:

(a) no consideration of generated and/or diverted non-agricultural traffic resulting from road improvement;
(b) negligible cost savings on transported agricultural inputs;
(c) no distinction between costs of transport during the wet and dry seasons;
(d) no distinction between normal and extreme deterioration of the road;
(e) no detours when section(s) of the rural road are impassable during the wet season;
(f) the same expected economic lives and implementation periods of all investments of the investment package;
(g) negligible salvage values of investments of the investment package;
(h) no benefits accruing to final consumers;
(i) no distinction between farm sizes in road's zone of influence;
(j) no additional cultivated land in the with-project situation;
(k) no introduction of new agricultural outputs and no increase in the number of crops per year in the with-project situation;
(l) no distinction between farm gate prices of on-farm consumption and exports from the road's zone of influence;
(m) small or zero elasticity of per-capita on-farm consumption as incomes increase;
(n) no consideration of on-farm consumption by animals;
(o) negligible road maintenance costs in the without-project situation; and

(p) the price elasticity of on-farm home consumption \[\text{the term } \frac{1}{2}(H_1 - H_2)(P_2 - P_1)\] is negligible (para. 30).

With the possible exception of items (1), (m), (n) and (o), the effect of the above assumptions on the ER and NPV criteria of an investment package is to understate them.
III. IDENTIFICATION METHOD

37. The purpose of this method is two-fold:

(a) to provide an inexpensive and practical tool for determining which investment packages of rural roads and complementary agricultural investments, out of a total program offered, warrant further consideration; and

(b) to provide a practical tool for examining alternative road and agricultural investment strategies of an investment package.

Identification is not a substitute for the more comprehensive investment package evaluation required in the final appraisal.

38. The Identification Method should recognize the uncertainty attached to the values of the various parameters and, in particular, to forecasts. The estimated costs of investments are likely to be more accurate than estimated future benefits accruing from them. Economic returns based on the Identification Method should, therefore, be tested with sensitivity analysis.

39. The Identification Method described here is based on all of the simplifying assumptions described in para. 36. The use of this method can be further simplified by applying it only to the most important outputs (products) in the road’s zone of influence rather than all outputs since in many instances the development potential of the zone of influence may depend primarily on the potential of one or two crops. In addition, rather than the establishment of annual costs and benefits streams (para. 35), one may calculate these streams for four representative years of the project implementation period and expected economic life (step 3 of para. 40) and obtain values of these streams for other years through interpolation. The step-by-step procedure of the following paragraph describes the Identification Method.
40. **Step 1:** Estimate the costs of investments of the investment package and their economic life.

**Step 2:** Estimate the annual road maintenance costs (routine and periodic) in the with-project situation.

**Step 3:** For each (or each important) output in the road's zone of influence, determine the agricultural production costs per ha of the without- and with-project situations in the first year of project implementation, the first year after project implementation, and the mid and last years of the expected project life.

**Step 4:** Fill out the following table for each (or each important) output in the road's zone of influence.

Table III.1: Product X -- Areas and Yields

<table>
<thead>
<tr>
<th>Year</th>
<th>W/O Areas ('000 ha)</th>
<th>With Areas ('000 ha)</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(6)</td>
</tr>
</tbody>
</table>

where, Year 1 = first year of project implementation
Year 2 = first year after project implementation
Year 3 = mid-year of expected project life
Year 4 = last year of expected project life
W/O areas = total of areas in the road's zone of influence utilized for the cultivation of product X in the without project situation
With areas unimproved = total of areas in the road's zone of influence utilized for the cultivation of product X in the with-project situation
situation with techniques similar to those of the without-project situation

With areas improved
- total of areas in the road's zone of influence utilized for the cultivation of product X in the with-project situation

Yield W/O
- yield of crop X with techniques similar to those of the without project situation

Yield with
- yield of crop X with techniques of the with project situation

Step 5: Estimate the road's zone of influence population for the four years of Step 3.

Step 6: For each (or each important) agricultural product of the road's zone of influence, determine the on-farm per capita consumption for the four years of Step 3 and the without- and with-project situations.

Step 7: Fill out the following table for each (or each important) output in the road's zone of influence.

Table III.2: Product X — Production, Home Consumption and Exports ('000 tons)

<table>
<thead>
<tr>
<th>Year</th>
<th>Production</th>
<th>Home Consumption</th>
<th>Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W/O</td>
<td>With</td>
<td>W/O</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
where Year 1, 2, 3 and 4 are as defined in Step 4,

Production W/O = number of ha of Column (2) of the Table III.1 times the yield of Column (5) of this table

Production with = number of ha of Column (3) of Table III.1 times the yield of Column (5) of this table plus number of ha of Column (4) of Table III.1 times the yield of Column (6) of this table

Home consumption W/O = population (Step 5) times the corresponding on-farm per-capita consumption in without project situation (Step 6)

Home consumption with = population (Step 5) times the corresponding on-farm per-capita consumption in with project situation (Step 6)

Exports W/O = the difference between Columns (2) and (4) of Table III.2

Exports with = the difference between Columns (3) and (5) of Table III.2

Step 8: For each transport means, estimate the per passenger-km and per ton-km fare and economic cost of transport in the without- and with-project situations.

Step 9: For each agricultural transport means, determine the average fare per ton-km and average transport cost per ton-km in the without- and with-project situations.¹/

Step 10: For each (or each important) agricultural product of the road's zone of influence, determine the farm-gate prices in the without- and with-project situation. The farm-gate price in the with-project situation equals that of the without-project situation plus the product of road distance and the difference between the fare in the without-project situation and the fare of the with-project situation (para. 21).

¹/ Taking into account transport savings due to reduction in vehicle operating costs on the improved road and changes in traffic mix in the with-project situation (para. 21).
Step 11: Fill out the following table for each (or each important) output in the road's zone of influence.

Table III.3: Product x — Values of Exports, Production Costs and Home Consumption Loss ($'000)

<table>
<thead>
<tr>
<th>Year</th>
<th>Exports</th>
<th>Net Incremental Export Values</th>
<th>Production Costs</th>
<th>Net Incremental Production Costs</th>
<th>Home Consumption Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W/O</td>
<td>With</td>
<td>W/O</td>
<td>With</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
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<tr>
<td>4</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

where Year 1, 2, 3 and 4 are as defined in Step 4,

- Exports W/O = exports of Column (6) of Table III.2 times the corresponding farm-gate price in the without-project situation (Step 10)
- Exports with = exports of Column (7) of Table III.2 times the corresponding farm-gate price in the with-project situation (Step 10)
- Net incremental export values = the difference between Columns (3) and (2) of Table III.3
- Production costs W/O = number of ha of Column (2) of Table III.1 times the corresponding agricultural production costs per ha in the without-project situation (Step 3)
- Production costs with = number of ha of Column (3) of Table III.1 times the corresponding agricultural production costs per ha in the without-project situation plus the number of ha of Column (4) of Table III.1 times the corresponding agricultural production costs per ha (Step 3)
- Net incremental production costs = the difference between Columns (6) and (5) of Table III.3
Home consumption loss = the product of the difference between Column (4) and Column (5) of Table III.2 times the corresponding farm-gate price of the without-project situation \([(H_1 - H_2)P_1]\)

Step 12: Fill out the following table for each (or each important) output in the road's zone of influence.

Table III.4: Product x — Transport Fares, Costs and Benefits ($'000)

<table>
<thead>
<tr>
<th>Year</th>
<th>Fares</th>
<th>Costs</th>
<th>Translporters' Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W/O</td>
<td>With</td>
<td>W/O</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
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<tr>
<td>4</td>
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</tr>
</tbody>
</table>

where Year 1, 2, 3 and 4 are as defined in Step 4,

Fares W/O = fares for transporting the exports over the rural road under consideration in the without-project situation, or Column (6) of Table III.2 times the road distance times the corresponding average fare per ton-km (Step 9)

Fares with = fares for transporting the exports over the rural road under consideration in the with-project situation, or Column (7) of Table III.2 times the road distance times the corresponding average fare per ton-km (Step 9)

Costs W/O = economic costs of transporting the exports over the rural road under consideration in the without-project situation, or Column (6) of Table II.2 times the road distance times the corresponding average transport cost per ton-km (Step 9)

Costs with = economic costs of transporting the exports over the rural road under consideration in the with-project situation, or Column (7) of Table II.2 times the corresponding average transport cost per ton-km (Step 9)
Transporters' benefits = [Columns (3) + (4)] minus [Columns (2) + (5)] of Table III.4

Step 13: For each means of non-agricultural traffic, estimate present and future (years 1, 2, 3 and 4 of Step 3) average daily traffic in the without- and with-project situations.

Step 14: Based on per passenger-km and ton-km cost of transport (Step 8) and present and future average daily traffic (Step 13), determine total cost of transport for each means of non-agricultural transport in the without- and with-project situations.

Step 15: Determine for all non-agricultural transport means the total cost savings for years 1, 2, 3 and 4 of Step 4 (difference between these costs in the without-project situation and these costs in the with-project situation).

Step 16: Based on the information established in Steps 1, 2, 11, 12 and 15, fill out the following table.

Table III.5: Aggregation of Net Costs and Benefits Streams ($'000)

<table>
<thead>
<tr>
<th></th>
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<tbody>
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<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
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<td></td>
</tr>
</tbody>
</table>

...
where

Year 1 = first year of project implementation

Year k = first year after project implementation

Year m = mid-year of expected project life

Year n = last year of expected project life

Investment costs

= investment costs of road improvements (construction) and agricultural complementary investments of investment package

Road maintenance costs

= costs of maintaining the improved (constructed) rural road

Net incremental agricultural production costs

= for years 1, k, m and n the summation over all agricultural products of the costs for years 1, 2, 3 and 4 of Column (7) of Table III.3, respectively; the incremental costs for years 2, 3, ..., (k - 1), (m + 1), (m + 2), ..., (n - 1) are obtained through interpolation

Net incremental export values

= for years 1, k, m and n the summation over all agricultural products of the values for years 1, 2, 3 and 4 of Column (4) of Table III.3, respectively; the incremental values for years 2, 3, ..., (k - 1), (m + 1), (m + 2), ..., (n - 1) are obtained through interpolation

Home consumption loss

= for years 1, k, m, and n the summation over all agricultural products of the losses for years 1, 2, 3 and 4 of Column (8) of Table III.3, respectively; the losses for years 2, 3, ..., (k - 1), (m + 1), (m + 2), ..., (n - 1) are obtained through interpolation

Transporters' benefits

= for years 1, k, m and n the summation over all agricultural products of the benefits for years 1, 2, 3 and 4 of Column (6) of Table III.4, respectively; the benefits for years 2, 3, ..., (k - 1), (m + 1), (m + 2), ..., (n - 1) are obtained through interpolation

Non-agricultural vehicle cost savings

= for years 1, k, m and n the summation over all agricultural products of the savings for years 1, 2, 3 and 4 of Step 15, respectively; the savings for years 2, 3, ..., (k - 1), (m + 1), (m + 2), ..., (n - 1) are obtained through interpolation
Step 17: With the costs and benefits streams of Table III.5, determine the ER and NPV of the investment package.

41. The techniques of ER and NPV computations are well known and, therefore, not illustrated here. Para. 37 stated that one purpose of the Identification Method is to provide a tool for examining alternative road and agricultural investment strategies of an investment package. This examination can be easily done by changing the investment costs of Column (2) of Table III.5 and introducing consequent changes in, for instance, agricultural yields, and therefore, modifications in the net incremental agricultural production costs and export values [Columns (4) and (5) of Table III.5]. In other words, the examination is done through a sensitivity analysis. For rural roads (development) projects, it may be particularly useful to test the sensitivity of key crops in order to obtain better perspective on the development potential of the area and the viability of the project. The techniques of sensitivity analysis, which can also be employed to test the sensitivity of the ER and NPV to estimated costs and benefits (para. 39), are also well known.

42. Many (or all) of the steps of the procedure of para. 40 could be carried out by regional offices of Agricultural and Public Works Ministries. Others may be better carried out by the central offices of these ministries. In Tunisia, for instance, it was proposed to give the responsibility of carrying out Steps 8, 9, 10 and 17 to the central offices and the remaining steps to the regional offices.
IV. RURAL ROADS PROGRAM

43. The purpose of the Rural Roads Program is to provide a detailed methodology for appraising investment packages of rural roads and complementary agricultural investments. None of the simplifying assumptions made in the Identification Method (para. 36) are made in the Rural Roads Program. The computations involved become, therefore, cumbersome if more than three different agricultural outputs with more than three inputs in a zone of influence are prevailing. A Rural Roads Computer Program (RRCP) has been developed to assist with the computations and sensitivity analyses. RRCP and a manual describing the preparation and coding of input data, the signing on to a time-sharing systems and the creation and editing of data files are available at the EMENA Projects Department of the World Bank.

44. In addition to removing the assumptions of para. 36, the Rural Roads Program differs from the Identification Method in that it:

(a) specifically recognizes existing interrelationships between the various parameters;

(b) provides for the simultaneously testing of two alternative road improvement situations and two alternative groups of complementary agricultural investment components, and combinations of these four alternatives (four "with-project situations");

(c) establishes a link between annual agricultural inputs and annual yields;

(d) computes for each transport means (agriculturally related and non-agricultural related) future average daily traffic on the rural road;
(e) facilitates the economic analysis of livestock development in the road's zone of influence;

(f) allows for the introduction of shadow prices; and

(g) determines the optimal time for implementing the investment package.

The following paragraphs describe the analytical framework of the Rural Roads Program. Simple symbols and indices are used to express the inter-relationships between the parameters.

45. The program consists of the following six models:

(1) the Transport Model, which involves two sub-models, (a) the Transport Costs and (b) the Farmer Benefits sub-models;

(2) the Agricultural Revenue Model, which includes (a) the Agricultural Production, (b) the Agricultural Inputs, (c) the Agricultural Revenue and (d) the Agricultural Investments sub-models;

(3) the Agricultural Traffic Model, including (a) the Local Consumption and Exports, (b) the Agricultural Traffic and (c) the Value of Local Consumption and Exports sub-models;

(4) the Distribution of Transport Savings Model, which involves (a) the Consumers' Surplus and (b) the Transporters' Surplus sub-models;

(5) the Non-Agricultural Traffic and Related Benefits Model, which includes (a) the Non-Agricultural Traffic, (b) the Related Benefits and (c) the Traffic sub-models; and

(6) the Economic Return Model, consisting of (a) the Costs and Benefits, (b) the ER and NPV and (c) the Optimal Year sub-models.
Indices. Various input variables are indexed in parentheses according to one or more of the following indices:

- **r** - index used to denote a link
- **s** - index used to denote two seasons (summer = 1, winter = 2)
- **rs** - index used to denote different road surface conditions; a maximum of 7 road surface conditions can be used
- **sp** - index used to denote different terrain types; a maximum of 4 terrain types can be used, as for example:
  - **sp=1** represents flat terrain
  - **sp=2** represents slightly undulating terrain
  - **sp=3** represents rolling terrain
  - **sp=4** represents mountaineous terrain
- **h** - index used to denote the planning horizon where:
  - **h1** or **h=1** means the beginning of planning horizon
  - **h2** or **h=2** means the end of planning horizon
- **v** - index used to denote a means of transportation; a maximum of 8 transport means can be used, as for example:
  - **v=1** represents transport by mule
  - **v=2** represents transport by mule plus cart
  - **v=3** represents transport by passenger car
  - **v=4** represents transport by van
  - **v=5** represents transport by truck
  - **v=6** represents transport by mini-bus
  - **v=7** represents transport by tractor
  - **v=8** represents transport by motorcycle
- **t** - index used to denote different types of traffic; a maximum of 4 traffic types can be used.
  - **t=1** represents passenger traffic using the project road
  - **t=2** represents commodity traffic using the project road
  - **t=3** represents passenger traffic diverted to the project road in one of the with-project situations
  - **t=4** represents commodity traffic diverted to the project road in one of the with-project situations
- **e** - index used for a route on the project road
- **f** - index used for an alternative route if the project road is impassable
- **n** - index to denote an external route or that portion of an internal route that does not contain the project road; an internal route is a route which contains the project road (Note that an alternate route could be an external route)
OD - index used to denote an origin-destination pair on a route; a maximum of 20 OD pairs can be used

ODe - index used to denote an origin-destination pair on route e

ODf - index used to denote an origin-destination pair on route f

ODn - index used to denote an origin-destination pair on route n

pt - index used to denote the degree of road improvements made during the planning horizon where:

ptl or pt=1 represents no road improvements in the road's zone of influence

pt=2 represents a certain level of improvements in the road's zone of influence

pt=3 represents another level of improvements in the road's zone of influence

pa - index used to denote the degree of agricultural investments made during the planning horizon where:

pal or pa=1 represents no agricultural investments in the zone of influence

pa=2 represents a certain level of agricultural investments in the road's zone of influence

pa=3 represents another level of agricultural investments in the road's zone of influence

p - index used to denote the degree of road improvements and/or agricultural investments made during the planning horizon, where:

pl or p=1 represents no road improvements and no agricultural investments in the road's zone of influence

p=2 represents a certain level of road improvements (pt=2) and a certain level of agricultural investments (pa=2) in the road's zone of influence

p=3 represents another level of road improvements (pt=3) and a certain level of agricultural investments (pa=2) in the road's zone of influence

p=4 represents a certain level of road improvements (pt=2) and another level of agricultural investments (pa=3) in the road's zone of influence

p=5 represents another level of road improvements (pt=3) and another level of agricultural investments (pa=3) in the road's zone of influence

The relation between pt, pa and p can be summarized as follows:
\[ \begin{array}{ccc}
I & p & p_a & p_t \\
1 & 1 & 1 & \\
2 & 2 & 2 & \\
3 & 2 & 3 & \\
4 & 3 & 2 & \\
5 & 3 & 3 & \\
\end{array} \]

I - index to denote the agricultural input used; a maximum of 17 agricultural inputs can be used, as for example:

- I=1 represents unspecialized labor (man-days/ha)
- I=2 represents specialized labor (man-days/ha)
- I=3 represents land used for the production of cereals (ha)
- I=4 represents land used for the production of rainfed tree products (olives, almonds) (ha)
- I=5 represents pasture land (ha)
- I=6 represents water (ton/ha)
- I=7 represents animal labor (day/ha)
- I=8 represents tractor use (hour/ha)
- I=9 represents material use (hour/ha)
- I=10 represents fodder (ton/ha)
- I=11 represents seeds (ton/ha)
- I=12 represents fertilizers (ton/ha)
- I=13 represents insecticides (ton/ha)
- I=14 represents credit requirements (monetary unit/ha)
- I=15 represents herbicides (ton/ha)
- I=16 represents fongicides (ton/ha)
- I=17 represents combine use (hour/ha)

If - index used to denote fodder input for cattle and sheep in the road's zone of influence

Note: The maximum number of agricultural inputs including fodder inputs are 17 (i.e., "If" belongs to I).

c - index to denote agricultural products; a maximum of 15 agricultural products can be used as for example:

- c=1 represents pasture land
- c=2 represents meat from cows
- c=3 represents milk from cows
- c=4 represents meat from sheep
- c=5 represents wheat
- c=6 represents barley
- c=7 represents fodder
- c=8 represents olives
- c=9 represents sunflower
- c=10 represents cereals on irrigated land
- c=11 represents tomatoes
- c=12 represents fodder on irrigated land
- c=13 represents vegetables
- c=14 represents potatoes
- c=15 represents corn
TRANSPORT MODEL

47. Transport Costs Sub-Model

47.1 The inputs to this model are:

1. For each transport type \( v \), the operating cost per km (\( v_{oc} \)) as a function of road surface condition \( r_s \) and terrain \( s_p \) (\( v=1, 2, \ldots, 8; r_s=1, 2, \ldots, 7; s_p=1, 2, \ldots, 4 \)) (monetary unit)

2. The list of the OD's taken into consideration for the analysis of the project road. OD's on route \( e \) are distinguished from those on route \( n \).

3. The list of links which lists each pair of OD's defining routes.

4. The matrix \( M \) which establishes the relation between each of the 8 transport means \( v \) and the four types \( t \) of traffic.

   Note: a. \( M \) is a matrix indicating the fractions of transport means \( v \) necessary to transport one ton of goods (or one passenger) of traffic type \( t \).

   b. \( M \) is given for the beginning and end of planning horizon (\( h=1 \) and \( 2 \)).

   c. \( M \) is a function of \( p_t \) and \( h \); consequently, there are 6 different matrices \( M \) since \( p_t=1, 2, 3 \) and \( h=1, 2 \).

5. Characteristics related to road sections of extreme deterioration and impassable road sections.

   \[ NSED(p_t, r, s) = \text{number of sections of extreme deterioration on link } r \]
   \[ \text{in each season of the without- and with project situations} \]
\[ \text{ED}(rs,v) = \text{the distance on a link with road surface R, or a}
\text{road section of extreme deterioration (rs) which}
\text{is equivalent to a distance on a link with road}
\text{surface condition R (per means of transport v)} \]

\text{Note: The surface condition R is refined as the}
\text{average condition of the seven surface conditions rs.}

\[ \text{PIOC}(v) = \text{the portion of operating costs of a transport means,}
\text{which is proportional to distance} \]

\[ \text{ANDI} = \text{average annual number of days that a road is}
\text{impassable} \]

\[ \text{ANDR} = \text{average annual number of days of rain} \]

The following information can be supplied for each link:

- identification number [number of province, number of rural road
(99), number of link (two digits)]
- number indicating the pt=1 or pt=2 or pt=3 project situation
- length
- terrain
- season (summer \( s=1 \), winter \( s=2 \))
- status of the road surface condition (rs) for summer \( s=1 \) and
winter \( s=2 \)
- number of sections of extreme deterioration for \( s=1 \) and \( s=2 \)

The following information can be supplied for each zone of influence
and for the without- or with-project situations (pt):

- the possible existence of impassable road sections during the
winter (rain) season
- the possible existence of an alternate route for the impassable
road section
- the links defining the alternate route (if existing)

47.2 The calculations of the Transport Cost Sub-Model are:

1. Cost of transport per means of transport \( v \) for each OD pair per
season of the without- and with-project situations (monetary unit), or

\[ \text{CTV}(\text{OD,pt,}\text{v,}\text{s}) = \sum_{r \in \text{OD}} \text{VOC}(\text{pt,}r,\text{v,}\text{s}) \times \text{d}(r) \]
where

\[ d(r) \] = length of link \( r \)

\[ \text{VOC}(pt,r,v,s) \] = cost for transport means \( v \), on link \( r \) during each season of the without- and with-project situations

2. Costs of transport per traffic \( t \) for each OD pair, per season of the without- and with-project situations and for the beginning and end of the planning horizon (monetary unit), or

\[
\text{CTTR}(OD,pt,t,h,s) = \sum_{v=1}^{8} M(pt,t,h,v) \times CTV(OD,pt,v,s)
\]

3. Cost of transport on sections of extreme deterioration per OD, per means of transport \( v \) and per season of the without- and with-project situations (monetary unit), or

\[
\text{CTEDV}(OD,pt,v,s) = \sum_{r \in \text{OD}} NSED(pt,r,s) \times ED(rs,v) \times PIOC(v)
\]

4. Cost of transport on sections of extreme deterioration, per OD, per means of traffic \( t \), per season of the without- and with-project situations (monetary unit), or

\[
\text{CTEDT}(OD,pt,t,h,s) = \sum_{v=1}^{8} M(pt,t,h,v) \times \text{CTEDV}(OD,pt,v,s)
\]

5. Costs of transport per traffic type \( t \) including the sections of extreme deterioration, per OD, per season of the without- and with-project situations and for the beginning and end of planning horizon (monetary unit), or

\[
\text{CTED}(OD,pt,t,h,s) = \text{CTTR}(OD,pt,t,h,s) + \text{CTEDT}(OD,pt,t,h,s)
\]

6. Cost of transport related to impassable section(s) (i.e., on route \( f \)) per means of traffic in the winter (rain) season of the without- and with-project situations and for the beginning and end of planning horizon (monetary unit)

- if an alternate route \( f \) exists, compute first

\[
\text{CTED}(OD_f,pt,t,h,2) \text{ in a manner similar to the computation of CTED of point 5 above and next}
\]

\[
\text{TTCT}(OD,pt,t,h,2) =
\]

\[
= \frac{(\text{ANDR} - \text{ANDI})[\text{CTED}(OD,pt,t,h,2)] + \text{ANDI}[\text{CTED}(OD_f,pt,t,h,2)]}{\text{ANDR}}
\]

- if no alternate route \( f \) exists, reduce the yields of specific products to reflect the loss in agricultural production due to impassable sections.

Note: The 2 in the CTED and TTCT formulas refer to \( s=2 \).
7. Reduction in costs of transport (benefit) per traffic type, per OD, per season of the two with-project situations and for the beginning and end of planning horizon (monetary unit)

- for OD's on route e

\[ DLTTCT(OD_e,pt,t,h,s) = [TTCT(OD_e,ptl,t,h,s)] - [TTCT(OD_e,pt,t,h,s)] \]

- for OD's on route n

\[ DLTTCT(OD_n,pt,t,h,s) = CTED(OD_f,ptl,t,h,s) - CTED(OD_n,pt,t,h,s) \]

Note: (1) If \( DLTTCT(OD,pt,t,h,s) < 0 \) for OD's on a route, then \( DLTTCT(OD,pt,t,h,s) = 0 \).

(2) \( pt \) in the second term of the above equations refers to one of the two with-project situations.

48. Farmer Benefits Sub-Model

48.1 This sub-model computes the portion of transport benefits accruing to the farmer (which is reflected in a reduction in farm-gate prices of agricultural inputs and an increase in farm-gate prices of agricultural outputs). The inputs to this sub-model are:

1. \( PIO(\text{pt}, h, s) \) = percentage of agricultural inputs and outputs transported by the farmer himself per season for the beginning and end of planning horizon of the without- and with-project situations

2. \( A(\text{pt}) \) and \( B(\text{pt}) \) = two given parameters depending on \( pt \) and which define the portion of transport benefits accruing to farmers

48.2 The calculations are:

\[ BF(\text{pt}, h, s) = A(\text{pt}) \times PIO(\text{pt}, h, s) + B(\text{pt}), \text{or the} \]

portion of transport benefits accruing to the farmer in a specific season during the beginning and end of planning horizon of the with-project situations; and

\[ DLTCF(OD_e,\text{pt}, h, s) = BF(\text{pt}, h, s) \times DLTTCT(OD_e,\text{pt}, t, h, s) \] or the reduction in transport costs accruing to the farmer and corresponding to the transport of agricultural inputs and outputs in the road's zone of influence per season of the with-project situations, per OD\( e \) and during the beginning and end of planning horizon (monetary unit).

49. In summary, the outputs of the TRANSPORT MODEL are:

1. Costs of transport per type of traffic and OD pair (monetary unit), or \( TTCT(\text{OD}, \text{pt}, t, h, s) \)

2. Reductions in costs of transport per type of traffic and OD pair or \( DLTTCT(\text{OD}, \text{pt}, t, h, s) \)
3. Portion of transport benefit accruing to the farmer, or BF(pt,h,s)

4. Reduction in transport cost accruing to the farmer (monetary unit), or DLTCF(ODE,pt,h,s)

AGRICULTURAL REVENUE MODEL

50. This model consists of four sub-models, i.e., Agricultural Production, Agricultural Inputs, Agricultural Revenue, and Agricultural Investments.

51. **Agricultural Production Sub-Model**

51.1 The inputs to this sub-model are:

1. TCAl(x) = total cultivated area in the zone of influence per size of farm for the without-project situation (ha)

2. TAA(pa,y) = total cultivable area per year (i.e., not cultivated but with potential to be cultivated) in the zone of influence for the without- and with project situations

3. CABl(u) = product area breakdown by farm size in the zone of influence for the without project situation (ha)

   Note that u indicates an activity by product and by farm size, or u = cx

4. ACA(pa,y,c) = additional cultivated area by product during each year in the zone of influence for the without- and with-project situations (pa = 1, 2, 3) (ha)

5. CICA(y,u) = completely improved cultivated area by product and farm size during each year in the zone of influence (ha)

6. PCICA(pa,y,c) = percentage of CICA, indicative of the adoption of new techniques by farmers during each year in the zone of influence for the without- and with-project situations and by product

7. YICL(y,u) = yield on improved cultivated land, by farm size, product and year (tons/ha)

8. YACL(y,u) = yield on additional cultivated land, by product, farm size and year (tons/ha)

9. YUCL(y,u) = yield on unimproved cultivated land, by farm size, product and year (tons/ha)

51.2 The calculations of the Agricultural Production Sub-Model are:
1. Product area breakdown after improvements have been introduced during each year in the zone of influence for the without- and with-project situations, by farm size and product (ha), or

\[ \text{CABI}(p_a,y,u) = \text{CABl}(u) \times [1 - \text{PCICA}(p_a,y,c)] + \text{CICA}(y,u) \times \text{PCICA}(p_a,y,c) \]

2. Percentage of improved area by product and farm size during each year in the zone of influence and for the without- and with-project situations, or

\[ \text{PRIA}(p_a,y,u) = \frac{\text{CICA}(y,u) \times \text{PCICA}(p_a,y,c)}{\text{CABI}(p_a,y,u)} \]

3. Total variation in product area breakdown by product and farm size during each year in the zone of influence and for the without- and with-project situations (ha), or

\[ \text{TVCAB}(p_a,y,u) = \text{CABI}(p_a,y,u) - \text{CABI}(p_a,1,u) \]

4. Annual variation in product area breakdown (incremental) by product, farm size and for the without- and with-project situations (ha), or

\[ \text{AVCICA}(p_a,y,u) = \text{TVCAB}(p_a,y,u) - \text{TVCAB}(p_a,y-1,u) \]

Note that \( \sum_u \text{TVCAB}(p_a,y,u) = 0 \)

\[ \sum_u \text{TVCAB}(p_a,y,u) = 0 \]

5. Improved cultivated area by product, farm size, and year of without- and with-project situations (ha), or

\[ \text{ICAB}(p_a,y,u) = \text{PRIA}(p_a,y,u) \times \text{CABI}(p_a,y,u) \]

6. Unimproved cultivated area by product, farm size and year of the without- and with-project situations (ha), or

\[ \text{UCAB}(p_a,y,u) = \text{CABI}(p_a,y,u) - \text{ICAB}(p_a,y,u) \]

7. Production on improved areas by product, farm size, and year of the without- and with-project situations (tons), or

\[ \text{PIA}(p_a,y,u) = \text{ICAB}(p_a,y,u) \times \text{YICL}(y,u) \]

8. Production on unimproved cultivated areas by product, farm size, and year of the without- and with-situations (tons), or

\[ \text{PUA}(p_a,y,u) = \text{UCAB}(p_a,y,u) \times \text{YUCL}(y,u) \]

9. Production of additional cultivated areas by product, and year of the two with-project situations (tons), or

\[ \text{PACA}(p_a,y,u) = \text{ACA}(p_a,y,u) \times \text{YACL}(y,u) \]
10. Total production by product, farm size, and year of the without- and with-project situations (tons), or

\[ TPC(pa,y,u) = PIA(pa,y,u) + PUA(pa,y,u) + PACA(pa,y,u) \]

11. Total production by product, and year of the without- and with-project situations (tons), or

\[ TP(pa,y,c) = \sum_{x=1}^{4} TPC(pa,y,(x,c)) \]

Note: The two principal input data are areas and yields. For cattle breeding (cows and sheep) the area is assumed to be equal to one hectare and the yield equal to total production. Product number 1 is always reserved for pasture land (it cannot be used if there is no pasture land). If the production of meat, milk and wool exists, the product numbers 2, 3 and 4 must be assigned to the production of meat, milk and wool. Thus, CABI(pa,y,u) are artificial areas for \( c=2, 3 \) and 4, and

\[ \sum_{c=2,3,4} CABI[pa,y,(c,x)] = TCA1(x) \quad \text{and} \quad \sum_{c=5} CABI[pa,y,(c,x)] = TCA1(x) - \sum_{c=2,3,4} CABI[pa,y,(c,x)] \]

where product number 1 refers to pasture land.

52. **Agricultural Inputs Sub-Model**

52.1 The inputs to this sub-model are:

1. \( IICA(I,u) \) = agricultural input I for improved cultivated areas during the first year of the planning horizon (\( h=1 \)), by product and farm size (tons/ha)

2. \( IUCA(I,u) \) = agricultural input I for unimproved cultivated areas during the first year of planning horizon (\( h=1 \)), by product and farm size (tons/ha)

3. \( IACA(I,u) \) = agricultural input I for additional, cultivated areas during the first year of the planning horizon (\( h=1 \)), by product and farm size (tons/ha)

4. \( GYICA(I,u) \) = parameter indicating the relation between growth of yield and the use of an agricultural input I for improved cultivated areas, by product and farm size

5. \( GYUCA(I,u) \) = parameter indicating the relation between the growth of yield and the use of an agricultural input I for unimproved cultivated areas, by product and farm size

6. \( GYACA(I,u) \) = parameter indicating the relation between the growth of yield and use of an agricultural input I for additional cultivated areas, by product and farm size
7. IT(I,c) = part of agricultural input I required for product and transported during the summer (dry) season over the project road under consideration (tons/ha)

8. WT(I,c) = part of water input for product c transported over the project road under consideration (tons/ha)

Note that WT(I,c) = 1 for I not equal to water.

52.2 The calculations of the Agricultural Inputs Sub-Model are:

1. AIICA(I,y,u) or the annual agricultural input I for improved cultivated areas by farm size and product (tons/ha)
   a. If IICA(I,u) ≠ 0
      \[ AIICA(I,y,u) = GYICA(I,u) \left( \frac{YICL(y,u)}{YICL(I,u)} - 1 \right) \] IICA(I,u) + IICA(I,u)
   b. If IICA(I,u) = 0
      \[ AIICA(I,y,u) = GYICA(I,u) \left( \frac{YICL(y,u)}{YICL(I,u)} - 1 \right) \]

2. AIUCA(I,y,u) or the annual agricultural input I for unimproved cultivated areas by farm size and product (tons/ha)
   a. If IUCA(I,u) ≠ 0
      \[ AIUCA(I,y,u) = GYUCA(I,u) \left( \frac{YUCL(y,u)}{YUCL(I,u)} - 1 \right) \] IUCA(I,u) + IUCA(I,u)
   b. If IUCA(I,u) = 0
      \[ AIUCA(I,y,u) = GYUCA(I,u) \left( \frac{YUCL(y,u)}{YUCL(I,u)} - 1 \right) \]

3. AIACA(I,y,u) or the annual agricultural input for additional cultivated areas by product (tons/ha)
   a. If IACA(I,u) ≠ 0
      \[ AIACA(I,y,u) = GYACA(I,u) \left( \frac{YACL(y,u)}{YACL(I,u)} - 1 \right) \] IACA(I,u) + IACA(I,u)
   b. If IACA(I,u) = 0
      \[ AIACA(I,y,u) = GYACA(I,u) \left( \frac{YACL(y,u)}{YACL(I,u)} - 1 \right) \]

4. TAI(pa,l,y,u) or total annual agricultural input I by product and farm size in the without- and with-project situations (tons/ha)
   \[ TAI(pa,l,y,u) = AIICA(I,y,u) \times ICAB(pa,y,u) + AIUCA(I,y,u) \times UCAB(pa,y,u) + AIACA(I,y,u) \times ACA(pa,y,c) \]
5. ITS(pa,y,u,s=1) or the quantities (tons) of agricultural inputs to be transported during the summer (dry) season, per year, per product, per farm size and in the without- and with-project situations

\[
\text{ITS}(pa,y,u,s=1) = \sum_{I \in E} \ IT(I,c) \ WT(I,c) \ [AIICA(I,y,u) \times ICAB(pa,y,u) + \ \text{IF-El} \\
+ \ AIUCA(I,y,u) \times UCAB(pa,y,u) + \ AIACA(I,y,u) \times ACA(pa,y,c)]
\]

where set El is the group of agricultural inputs to be transported (there may also be agricultural inputs produced and consumed on the farm).

6. ITS(pa,y,u,s=2) or the quantities (tons) of agricultural inputs to be transported during the winter (rain) season, per year, per product, per farm size and in the without- and with-project situations

\[
\text{ITS}(pa,y,u,s=2) = \sum_{I \in E} [1 - IT(I,c)] \times WT(I,c) \times AIICA(I,y,u) \times ICAB(pa,y,u) + \ \text{IF-El} \\
+ \ AIUCA(I,y,u) \times UCAB(pa,y,u) + \ AIACA(I,y,u) \times ACA(pa,y,c)
\]

53. Agricultural Revenue Sub-Model

53.1 The inputs to this sub-model are:

1. FAC1(c) = farm-gate efficiency price of agricultural product c produced in the road's zone of influence in the without-project situation (monetary unit/ton)

2. FAIFL(I,c) = farm-gate efficiency price of agricultural input I for product c (with no shadow price for family labor) (monetary unit/ton)

3. FAEFL(I,c) = farm-gate price of agricultural input I for product c (with a shadow price for family labor) (monetary unit/ton)

4. K(c) = part of agricultural product c transported during the summer (dry) season

5. L(c) = part of agricultural product c transported during the winter (rain) season; note that K(c) = 1 - L(c)

6. SPI(I) = coefficient which, when multiplied by the efficiency price of an agricultural input I, gives its shadow price

7. HL(x,I) = parameter indicating the percentage of hired labor, by farm size and agricultural input

53.2. The computations of this sub-model are:

1. Farm-gate shadow price of agricultural inputs by product (monetary unit/ton), or

\[
\text{FISPI}(I,c) = \frac{\sum_{x=1}^{4} TCAI(x)[HL(x,I) + (1 - HL(x,I)) SPI(I)]}{\sum_{x=1}^{4} TCAI(x)}
\]
2. Value of production by type of agricultural product, farm size and during each year of the planning horizon of the without-project situation (monetary unit), or

\[ VP(\text{pl}, y, u) = TPC(\text{pal}, y, u) \times FACL(c) \]

Note: pl represents the without project situation.

3. Costs of agricultural inputs per product, farm size and during each year of the planning horizon of the without-project situation (monetary unit), or

\[ CIIFL(\text{pl}, y, u) = \sum_{I} TAI(\text{pal}, I, y, u) \times FISPI(I, c) \]

4. Costs of agricultural inputs (with a shadow price for family labor) per product, farm size and during each year of the planning horizon the without-project situation (monetary unit), or

\[ CIEFL(\text{pl}, y, u) = \sum_{I} TAI(\text{pal}, I, y, u) \times FAEFL(I, c) \]

5. Revenue by product, farm size and during each year of the planning horizon of the without-project situation (monetary unit), or

\[ RIFL(\text{pl}, y, u) = VP(\text{pl}, y, u) - CIIFL(\text{pl}, y, u) \]

6. Revenue (with a shadow price for family labor) by product, farm size and during each year of the planning horizon of the without-project situation (monetary unit), or

\[ REFL(\text{pl}, y, u) = VP(\text{pl}, y, u) - CIEFL(\text{pl}, y, u) \]

7. Total revenue during each year of the planning horizon of the without-project situation (monetary unit), or

\[ TRIFL(\text{pl}, y) = \sum_{u} RIFL(\text{pl}, y, u) \]

8. Total revenue (with a shadow price for family labor) in the without-project situation during each year of the planning horizon (monetary unit), or

\[ TREFL(\text{pl}, y) = \sum_{u} REFL(\text{pl}, y, u) \]

9. Annual transport savings accruing to farmers in each season during each year of the planning horizon of the with-project situations (monetary/unit), or

\[ DLTCF(\text{ODE, pt}, y, s) = DLTCF(\text{ODE, pt}, 1, s) + [DLTCF(\text{ODE, pt}, 2, s) - DLTCF(\text{ODE, pt}, 1, s)] \times \frac{y-1}{h1-h2} \]
14. Farm-gate efficiency price of product c transported over the project road during each year of the planning horizon of the without- and with-project situations (monetary unit/ton), or

\[ FP(pt,y,c) = FACl(c) + K(c) \times DLTCF(ODE,pt,y,s=1) + \]
\[ + L(c) \times DLTCF(ODE,pt,y,s=2) \]

Note that DLTCF(ODE,pt,y,s) is the average over all ODe's on route e and that FP(pt,y,c) = FACl(c) for agricultural products consumed on the farm (products in group E2 or the group of fodder products).

15. Farm-gate efficiency price of agricultural input I transported over the project road for product c during each year of the planning horizon of the without- and with-project situations (monetary unit/ton), or

\[ FIIFL(pt,I,y,c) = FISPI(I,c) - IT(I,c) \times WT(I,c) \times DLTCF(ODE,pt,y,s=1) - \]
\[ - [1 - IT(I,c)] \times WT(I,c) \times DLTCF(ODE,pt,y,s=2) \]

16. Farm-gate price (with a shadow price for family labor) of an agricultural input I being transported over the project road for product c during each year of the planning horizon of the without- and with-project situations (monetary unit/ton), or

\[ FIEFL(pt,I,y,c) = FAEFL(I,c) - IT(I,c) \times WT(I,c) \times DLTCF(ODE,pt,y,s=1) - \]
\[ - [1 - IT(I,c)] \times WT(I,c) \times DLTCF(ODE,pt,y,s=2) \]

17. Value of production by type of product and farm size and during each year of the planning horizon of the with-project situations (monetary unit), or

\[ VP(p,y,u) = TPC(pa,y,u) \times FP(pt,y,c) \]

18. Costs of agricultural inputs per product, farm size and during each year of the planning horizon of the with-project situations (monetary unit), or

\[ CIIFL(p,y,u) = \sum TAI(pa,I,y,u) \times FIIFL(pt,I,y,c) \]

19. Costs of agricultural inputs (with a shadow price for family labor) per project, farm size and during each year of the planning horizon of the with-project situations (monetary unit), or

\[ CIEFL(p,y,u) = \sum TAI(pa,I,y,u) \times FIEFL(pt,I,y,c) \]

20. Revenue by product, farm size and during each year of the planning horizon of the with-project situations (monetary unit), or

\[ RIFL(p,y,u) = VP(p,y,u) - CIIFL(p,y,u) \]
17. Revenue (with a shadow price for family labor) by product and farm size and during each year of the planning horizon of the with-project situations (monetary unit/ton), or

\[ \text{REFL}(p,y,u) = \text{VP}(p,y,v) - \text{CIEFL}(p,y,u) \]

18. Total revenue during each year of planning horizon of the with-project situations (monetary unit), or

\[ \text{TRIFL}(p,y) = \sum U \text{RIFL}(p,y,u) \]

19. Total revenue (with a shadow price for family labor) during each year of planning horizon of the with-project situations (monetary unit), or

\[ \text{TREFL}(p,y) = \sum U \text{REFL}(p,y,u) \]

20. Change in annual revenue (monetary unit), or

\[ \text{DLRIFL}(p,y) = \text{TRIFL}(p,y) - \text{TRIFL}(p1,y) \]

21. Change in annual revenue (with a shadow price for family labor; monetary unit), or

\[ \text{DLREFL}(p,y) = \text{TREFL}(p,y) - \text{TREFL}(p1,y) \]

22. Change in the annual value of total production (monetary unit), or

\[ \text{DLVP}(p,y) = \sum U \text{VP}(p,y,u) - \sum U \text{VP}(p1,y,u) \]

23. Change in annual costs of agricultural inputs (monetary unit), or

\[ \text{DLCIFL}(p,y) = \sum U \text{CIIFL}(p,y,u) - \sum U \text{CIIFL}(p1,y,u) \]

24. Change in annual costs of agricultural inputs (with a shadow price for family labor; monetary unit), or

\[ \text{DLCEFL}(p,y) = \sum U \text{CIEFL}(p,y,u) - \sum U \text{CIEFL}(p1,y,u) \]

54. Agricultural Investments Sub-Model

54.1 The inputs to this model are:

1. \( \text{CIIA}(y,u) \) = investment costs to significantly improve areas for product c of farm size x during each year of the planning horizon (monetary unit/ha)

2. \( \text{ICCL}(y,u) \) = investment costs to cultivate cultivable land for product c of farm size x during each year of the planning horizon (monetary unit/ha)

3. \( \text{INCNP}(y,u) \) = investment costs of new plantations for product c of farm size x during each year of the planning horizon (monetary unit/ha)
54.2 The calculations are:

1. Variations in improved areas by type of product and farm size during each year of the without- and with-project situations (ha), or

\[ \text{AVICAB}(p,a,y,u) = \text{ICAB}(p,a,y,u) - \text{ICAB}(p,a,y-1,u) \]

2. Variations in additional cultivated areas by product and farm size during each year of the without- and with-project situations (ha), or

\[ \text{AVACA}(p,a,y,u) = \text{ACA}(p,a,y,c) - \text{ACA}(p,a,y-1,c) \]

3. Cost of investment to improve areas during year \( y \) for product \( c \) of farm size \( x \), for the without- and with-project situations (monetary unit), or

\[ \text{ICIA}(p,y-1,u) = \text{AVICAB}(p,a,y,u) \times \text{CIIA}(y,u) \]

4. Total costs of improving areas during year \( y \) for all farm sizes and products of the without- and with-project situations (monetary unit), or

\[ \text{TICIA}(p,y) = \sum_{u} \text{ICIA}(p,y,u) \]

5. Cost of investment to cultivate cultivable land during year \( y \) for product \( c \) of farm size \( x \), for the without- and with-project situations (monetary unit), or

\[ \text{ICCA}(p,y-1,u) = \text{AVACA}(p,a,y,u) \times \text{ICCL}(y,u) \]

6. Total costs of cultivating cultivable land during year \( y \) for all farm sizes and products of the without and with project situations (monetary unit), or

\[ \text{TICCA}(p,y) = \sum_{u} \text{ICCA}(p,y,u) \]

7. Cost of investment for new plantations during year \( y \) for product \( c \) of farm size \( x \) of without and with-project situations (monetary unit), or

\[ \text{ICNP}(p,y-1,u) = \text{AVCICA}(p,a,y,u) \times \text{INCNP}(y,u) \]

8. Total costs of investments for new plantations during year \( y \) for all farm sizes and products of the without- and with-project situations (monetary unit), or

\[ \text{TICNP}(p,y) = \sum_{u} \text{ICNP}(p,y,u) \]

**AGRICULTURAL TRAFFIC MODEL**

55. This model consists of three sub-models, i.e., Local Consumption and Exports, Agricultural Traffic, and Value of Local Consumption and Exports. Local consumption refers to agricultural products produced in the rural road's zone of influence and consumed by people living in this zone. Exports refer
to agricultural products produced in the rural road's zone of influence and exported outside this zone.

56. **Local Consumption and Exports Sub-Model**

56.1 The inputs to this sub-model are:

1. \( \text{POP}(pa,y) \) = zone's population during year \( y \) of the without- or with-project situation

2. \( \text{LCC}(pl,1,c) \) = local per-capita consumption of product \( c \) during the first year of the planning horizon (\( h=1 \)) of the without-project situation (tons/capita)

3. \( \text{ECC}(c) \) = elasticity of per-capita consumption of product \( c \)

4. \( \text{CF} \) = conversion factor between an animal-hour of transport and on-farm services and the corresponding fodder intake

5. \( \text{PEF}(pa,If,y) \) = a zero-one integer to control the local consumption/exports of fodder products during year \( y \) of the without- and with-project situations

\( \text{Note: A zero value is assigned to ensure no exports of a fodder product from the zone of influence; otherwise, one.} \)

56.2 The calculations of the Local Consumption and Exports Sub-Models are:

1. Average per-capita revenue for each year of the without- and with-project situations (tons/capita), or

\[ \text{ACR}(p,y) = \frac{\text{TREFL}(p,y)}{\text{POP}(pa,y)} \]

2. Local per-capita consumption by product and year of the without- and with-project situations (tons/capita), or

\[ \text{LCC}(p,y,c) = \text{LCC}(pl,1,c) \times [\frac{\text{ACR}(p,y)}{\text{ACR}(p,1)}]^{\text{ECC}(c)} \]

3. Total consumption by product and year of the without- and with-project situations (tons), or

\[ \text{TLCC}(p,y,c) = \text{POP}(pa,y) \times \text{LCC}(p,y,c) \]

4. Comparison of local production and local consumption of product \( c \):

\[ \text{COMPl}(p,y,c) = \text{TP}(pa,y,c) - \text{PLCC}(p,y,c) \]

If \( \text{COMPl}(p,y,c) < 0 \), set \( \text{TLCC}(p,y,c) = \text{TP}(pa,y,c) \)
5. Total local consumption of all products locally produced during year $y$ of the without- and with-project situations (tons), or

$$\text{TTLCC}(p,y) = \sum_c \text{TLCC}(p,y,c)$$

Note: The above expressions deal with local consumption by people. The following expressions deal with local consumption by animals.

6. Local consumption of fodder products by animals bred for meat, milk and wool production during each year of the planning horizon of the without- and with-project situations (tons), or

$$\text{LCFA}(p_a,y) = \sum \sum \text{TAI}(p_a,If,y,u) \times \text{PEF}(p_a,If,y)$$

7. Local consumption by animals kept for transport and on-farm services during each year of the planning horizon of the without-and with-project situations (tons), or

$$\text{LCFTA}(p_a,y) = \sum \sum \text{TAI}(p_a,If,y,u) \times \text{PEF}(p_a,If,y)$$

8. Total fodder inputs during each year of planning horizon of the without- and with-project situations (tons), or

$$\text{TFI}(p_a,y) = \text{LCFA}(p_a,y) + \text{LCFTA}(p_a,y)$$

9. Comparison of local production and local consumption by animals during each year of the planning horizon of the without- and with project situations (tons); or

$$\text{COMP2}(p_a,y) = \sum \sum \text{TP}(p_a,y,c) \times \text{PEFP}(p_a,y,c) - \text{TFI}(p,y)$$

if $\text{COMP2}(p_a,y) > 0$, local consumption $= \text{TFI}(p,y)$

if $\text{COMP2}(p_a,y) < 0$, local consumption $= \text{TP}(p_a,y,c)$

Note: $E_2$ represents the group of fodder products.

10. Exportable surplus by product and year of the without- and with-project situations for products other than fodder (tons), or

$$\text{EXSU}(p,y,c) = \text{TP}(p_a,y,c) - \text{TLCC}(p,y,c)$$

11. Exportable surplus of fodder products during each year of the planning horizon of the without- and with-project situations (tons), or

$$\text{EXSUF}(p_a,y) = \text{COMP2}(p_a,y), \text{if COMP2}(p_a,y) \geq 0, \text{ and}$$

$$\text{EXSUF}(p_a,y) = 0, \text{if COMP2} (p_a,y) < 0$$

12. Total exportable surplus during each year of the planning horizon of the without- and with-project situations (tons), or
TEXSU(p,y) = EXSUF(p,y) + Σ EXSU(p,y,c)

57. **Agricultural Traffic Sub-Model**

57.1 This sub-model does not require any new input data.

57.2 The calculations are:

1. Matrices M on a year-to-year basis (by extrapolation), or

   \[ M(pt,t,y,v) = M(pt,t,hl,v) + \frac{M(pt,t,h2,v) - M(pt,t,hl,v)}{(h2-h1)}(y-1) \]

2. Average daily traffic by means of transport v and related to the exports of agricultural products during each year of the planning horizon of the without- and with-project situations (transport means/day), or

   \[ ADTE(p,y,v) = \frac{1}{365} M(pt,t=2,y,v) \times TEXSU(p,y) \]

3. Total imports of agricultural inputs during each year of the planning horizon of the without- and with-project situations (tons), or

   \[ TIAI(pa,y) = \sum_u [ITS(pa,y,u,s=1) + ITS(pa,y,u,s=2)] \]

4. Average daily traffic by means of transport v and related to the imports of agricultural inputs during each year of the planning horizon of the without- and with-project situations (transport means/day), or

   \[ ADTI(p,y,v) = \frac{1}{365} M(pt,t=2,y,v) \times TIAI(pa,y) \]

5. Average daily traffic resulting from agricultural activities in zone of influence, by means of transport v during each year of the planning horizon of the without- and with-project situations (transport means/day), or

   \[ ADTEI(p,y,v) = ADTE(p,y,v) + ADTI(p,y,v) \]

6. Average daily motorized traffic resulting from agricultural activities in the zone of influence during each year of the planning horizon of the without- and with-project situations (vehicles/day), or

   \[ ADTM(p,y) = \frac{8}{3} \sum_v ADTEI(p,y,v) \]

   Note: \( v=1 \) and \( v=2 \) are assumed to be non-motorized means of transport; all other \( v \) are assumed to be motorized means of transport.

7. Average daily animal traffic resulting from agricultural activities in the zone of influence during each year of the planning horizon of the without- and with-project situations (animals or animal carts/day), or

   \[ ADTA(p,y) = \sum_{v=1}^2 ADTEI(p,y,v) \]
Value of Local Consumption and Exports Sub-Model

This sub-model requires only one input data:

\[ FLCCl(c) = \text{farm-gate efficiency price for locally consumed product } c \text{ of the without-project situation (monetary unit/tons)} \]

The calculations of this sub-model are:

1. Farm-gate efficiency price of exports in the without-project situations (monetary unit/ton)
   a. For non-fodder products:
      \[ FEPl(c) = \left( \frac{TP(pal,y=1,c) \times FACl(c) - TLCC(p,y=1,c) \times FLCCl(c)}{EXSU(p1,y=1,c)} \right) \]
      if \( EXSU(p1,y=1,c) = 0 \), then \( FEPl(c) = FLCCl(c) \).
   b. For fodder products:
      \[ FEF1(c) = \sum_{c \in E2} \left( \frac{TP(pal,y=1,c) \times FACl(c) - TLCC(p,y=1,c) \times FLCCl(c)}{EXSU(p1,y=1)} \right) \]
      if \( EXSU = 0 \), then \( FEF1(c) = FLCCl(c) \).

2. Farm-gate efficiency price of exports in with-project situations (monetary unit/ton)
   a. For non-fodder products:
      \[ FEP(pt,y,c) = FEPl(c) + K(c) \times DLTCF(ODE,pt,y,s=1) + L(c) \times DLTCF(ODE,pt,y,s=2) \]
   b. For fodder products:
      \[ FEF(p,y) = FEF1(cf) + K(cf) \times DLTCF(ODE,pt,y,s=1) + L(cf) \times DLTCF(ODE,pt,y,s=2) \]

3. Value of exports during each year of the without- and with-project situations (monetary unit)
   a. For products other than fodder (by product):
      \[ VEC(p,y,c) = EXSU(p,y,c) \times FEP(pt,y,c) \]
   b. For total of fodder products:
      \[ VECF(p,y) = EXSU(pa,y) \times FEF(p,y) + \sum_{c \in E2} EXSU(p,y,c) \]

4. Value of local consumption during each year of the without- and with-project situations (monetary unit)
a. For products other than fodder (by product):

\[ VLCC(p,y,c) = VP(p,y,c) - VEC(p,y,c) \]

b. For total of fodder products:

\[ VLCCF(p,y,c) = \sum_{c \in \mathbb{E}^2} VP(p,y,c) - VECF(p,y) \]

5. Total value of exports (all products) during each year of the planning horizon of the without- and with-project situations (monetary unit), or

\[ TVE(p,y) = \sum_{c \in \mathbb{E}^2} VEC(p,y,c) + VECF(p,y) \]

6. Total value of local consumption during each year of the planning horizon of the without- and with-project situations (monetary unit), or

\[ TVLC(p,y) = \sum_{c \in \mathbb{E}^2} VLCC(p,y,c) + VLCCF(p,y) \]

DISTRIBUTION OF TRANSPORT SAVINGS MODEL

59. This model treats increased values accruing to: (i) consumers, and (ii) transporters and other intermediate organizations. It consists of the Consumers' Surplus Sub-Model and the Transporters' Surplus Sub-Model.

60. Consumers' Surplus Sub-Model

60.1 The input to this sub-model is:

\[ BC(pt) = \text{portion of the transport savings accruing to the consumer} \]

60.2 The calculations are:

1. Annual transport savings for traffic type 2, per season and year of the with-project situations (monetary unit), or

\[ DLCT2(ODe,pt,y,s) = DLTTCT(ODe,pt,t=2,h1,s) + [DLTTCT(ODe,pt,t=2,h2,s) - DLTTCT(ODe,pt,t=2,h1,s) \times \frac{y-1}{h2-h1}] \]

Note: Traffic type 2 is commodity traffic using the project road.

2. Annual transport savings by product and year of the with-project situations (monetary unit), or

\[ DLCTC(pt,y,c) = K(c) DLCT2(pt,y,s=1) + L(c) DLCT2(pt,y,s=2) \]

3. Consumer surplus by product and year of the without- and with-project situations (monetary Unit), or
- For all products other than fodder:
\[
\text{CSC}(p,y,c) = BC(pt) \times DLCTC(pt,y,c) \left[ \frac{\text{EXSU}(p,y,c) + \text{EXSU}(p_{L},y,c)}{2} \right]
\]

- For fodder products:
\[
\text{CSC}(p,y,cf) = BC(pt) \times DLCTC(pt,y,cf) \left[ \frac{\text{EXSU}(p,y,cf) + \text{EXSU}(p_{L},y,cf)}{2} \right]
\]

4. Total consumer surplus of all fodder and non-fodder products by year of the without- and with-project situations (monetary unit), or
\[
\text{TCSC}(p,y) = \sum_{c} \text{CSC}(p,y,c)
\]

61. **Transporters' Surplus Sub-Model**

61.1 The inputs to this model are:

1. \( \text{PBT} = \) the benefit (transport price minus transport cost) accruing to the transporter (expressed as a percentage of the transport cost)

2. \( \text{AVL}(v) = \) average load of transport means \( v \) (tons)

61.2 The calculations are:

1. \( \text{BT}(pt,h,s) = 1 - BF(pt,h,s) - BC(pt) \)
\[
\text{BT}(pt,y,s) = \text{BT}(pt,hl,s) + [\text{BT}(pt,h2,s) - \text{BT}(pt,hl,s)] \times \frac{y-1}{h2-hl}
\]

2. Motorized agricultural traffic in year \( y \) of the with-project situations (transport means/day), or
\[
\text{MAT}(pt,y) = \sum_{v=3}^{8} M(pt,t=1,y,v) \times \text{AVL}(v) + M(pt,t=2,y,v) \times \text{AVL}(v)
\]

3. Quantities transported during the summer (dry) season and related to the agricultural activities in the road's zone of influence by product and year of the without- and with-project situations (tons), or

- For all products other than fodder:
\[
\text{IQT}(p,y,c,s=1) = \sum_{x=1}^{4} \text{ITS}(pa,y,u,s=1) + K(c) \text{EXSU}(p,y,c)
\]

- For fodder products:
\[
\text{IQT}(p,y,cf,s=1) = \sum_{x=1}^{4} \text{ITS}(pa,y,u,s=1) + K(cf)[\text{EXSU}(pa,y) + \text{EXSU}(p,y,cf)]
\]

4. Quantities transported during the winter (rainy) season and related to the agricultural activities in the road's zone of influence by product and year of the without- and with-project situations (tons), or
- For all products other than fodder:
  \[ \text{IQT}(p,y,c,s=2) = 4 \sum_{x=1}^{4} \text{ITS}(pa,y,u,s=2) + K(c) \text{EXSU}(p,y,c) \]

- For fodder products:
  \[ \text{IQT}(p,y,cf,s=2) = \text{ITS}(pa,y,u,s=2) + K(cf)[\text{EXSU}(pa,y) + \text{EXSU}(p,y,cf)] \]

5. Annual benefits accruing to transporter in each season of the without- and with-project situations for OD's on route e (monetary unit), or

First:
  \[ \text{ABT}(ODe,pt,h,s) = [1 - \text{PIO}(pt,h,s)] \times [\text{TTCT}(ODe,pt,t=2,h,s)] \times \text{PBT} \]
  for \( h=1 \) and \( h=2 \)

Next:
  \[ \text{ABT}(ODe,pt,y,s) = \text{ABT}(ODe,pt,hl,s) + [\text{ABT}(ODe,pt,h2,s) - \text{ABT}(ODe,pt,hl,s)] \times \frac{y-1}{h2-h1} \]

6. Transporters' surplus by product and year of the without- and with-project situations (monetary unit), or

\[ \text{TSU}(p,y,c) = \sum_{s=1}^{2} \text{IQT}(p,y,c,s) \times \text{BT}(pt,y,s) \times \text{DLCT2}(pt,y,s) + \text{MAT}(pt,y) \times \text{ABT}(pt,y,s) \times [\text{IQT}(p,y,c,s) - \text{IQT}(pl,y,c,s)] \]
  if \( \text{IQT}(p,y,c,s) - \text{IQT}(pl,y,c,s) > 0 \)

\[ \text{TSU}(p,y,c) = \sum_{s=1}^{2} \text{IQT}(p,y,c,s) \times \text{BT}(pt,y,s) \times \text{DLCT2}(pt,y,s) \]
  if \( \text{IQT}(p,y,c,s) - \text{IQT}(pl,y,c,s) < 0 \)

Note: \( \text{DLTC2}(pt,y,s) \) is the average of \( \text{DLTC2}(ODe,pt,y,s) \) over all OD's on route e (ODe).

7. Total transporters surplus by year of the without- and with-project situations (monetary unit), or

\[ \text{TTSU}(p,y) = \sum_{c} \text{TSU}(p,y,c) \]

NON-AGRICULTURAL TRAFFIC AND RELATED BENEFITS MODEL

62. This model consists of three sub-models, i.e., the Non-Agricultural Traffic, the Related Benefits and the Traffic Sub-Models.

63. **Non-Agricultural Traffic Sub-Model**

63.1 The inputs to this sub-model are:
average daily traffic of type t=1 on each OD pair of route e during each year of the planning horizon of the without-project situation (passenger/day)

2. ADT2(ODE,ptl,y) = average daily non-agricultural traffic of type t=2 on each OD pair of route e during each year of the planning horizon of the without-project situation (tons/day)

3. ADT3(ODn,y) = average daily traffic of type t=3 on each OD pair of route n during each year of the planning horizon (passengers/day)

4. ADT4(ODn,y) = average daily traffic of type t=4 on each OD pair of route n during each year of the planning horizon (tons/day)

5. EL1 = elasticity coefficient for the calculation of generated traffic of type t=1

6. EL3 = elasticity coefficient for the calculation of generated traffic of type t=3

6.2 The calculations of this sub-model are:

1. Generation factor for traffic type t=1 on OD's of route e during each season of the without- and with-project situations and for the beginning and end of the planning horizon, or

\[ GFT1(ODE,pt,h,s) = [1 - \frac{DLTTCT(ODE,pt,l,h,s)}{TTCT(ODE,pt,l,h,s)}] - EL1 - 1 \]

2. Average generation factor for traffic type t=1 for OD's of route e during the beginning and end of the planning horizon of the without- and with-project situations, or

\[ AGFT1(ODE,pt,h) = \frac{(365 - ANDR) GFT1(ODE,pt,h,1) + ANDR X GFT1(ODE,pt,h,2)}{365} \]

Note: Generated commodity traffic is not considered.

3. Interpolation of the average generation factor for traffic type t=1, or

\[ AGFT1(ODE,pt,y) = AFGT1(ODE,pt,hl) + [AGFT1(ODE,pt,h2) - AFGT1(ODE,pt,hl)] X \frac{y - 1}{h2 - hl} \]

4. Average daily traffic of type t=1 for OD's of route e during each year of the planning horizon of the with-project situations (passengers/day), or

\[ ADT1(ODE,pt,y) = ADT1(ODE,ptl,y) X [1 + AGFT1(ODE,pt,y)] \]

5. Average daily traffic of type t=3, during each year of the planning horizon of the without- and with-project situations (passengers/day), or
(365 - ANDR) \sum ADT3(ODn,y) + ANDR \sum ADT3(ODn,y) \\
\frac{ODnE(3,1)}{365} + \frac{ODnE(3,2)}{365}

where ODnE(3,s) = group of OD's for which DLTTCT(ODn,pt,t=3,y,s) > 0

6. Average daily traffic of type t=4 during each year of the planning horizon of the without- and with-project situations (tons/day), or

(365 - ANDR) \sum ADT4(ODn,y) + ANDR \sum ADT4(ODn,y) \\
\frac{ODnE(4,1)}{365} + \frac{ODnE(4,2)}{365}

where ODnE(4,s) = group of OD's for which DLTTCT(ODn,pt,t=4,y,s) > 0

7. Generation factor for long distance passenger traffic on OD's belonging to E(3,s) and route n in each season of the without- and with-project situations and for the beginning and of planning horizon, or

GFT3(ODn,pt,h,s) = [1 - \frac{DLTTCT(ODn,pt,3,h,s)}{TTCT(ODn,pt,3,h,s)}]^{EL3} - 1

GFT3(ODn,pt,h,s) = 0, if DLTTCT(ODn,pt,3,h,s) < 0

8. Average generation factor for long distance passenger traffic in the without- and with-project situations and for the beginning and end of planning horizon, or

AGFT3(ODn,pt,h) = \frac{(365 - ANDR) GFT3(ODn,pt,h,1) + ANDR GFT3(ODn,pt,h,2)}{365}

9. Interpolation of the average generation factor for long distance traffic, or

AGFT3(ODn,pt,y) = AGFT3(ODn,pt,hl) + [AGFT3(ODn,pt,h2) - AGFT3(ODn,pt,hl)] \times \\
\frac{y-1}{h2-hl}

10. Generated long-distance passenger traffic per OD and for the total of OD's during each year of the planning horizon of the without- and with-project situations (passenger/day), or

GT3(ODn,pt,y) = ADT3(ODn,y) \times AGFT3(ODn,pt,y)

TGT3(pt,y) = \sum GT3(ODn,pt,y)

64. **Related Benefits Sub-Model**

64.1 No additional inputs are required.

64.2 The calculations of this sub-model are:

1. Reduction in costs of transport per OD, per traffic type, per season and during each year of the planning horizon of the without- and with-project situations (monetary unit), or
2. Average reduction in daily transport costs, per OD, per traffic type and during each year of the planning horizon of the without- and with-project situations (monetary unit), or

For \( t = 1, 2, 3 \) and \( 4 \):

\[
DLTCT(OD,pt,t,y,s) = DLTCT(OD,pt,t,h1,s) + \left[ DLTCT(OD,pt,t,h2,s) - \frac{DLTCT(OD,pt,t,h1,s)}{h2-h1} \right]^{y-1}/h2-h1
\]

3. Annual benefits related to traffic type \( t = 1 \) for each and all OD's of route \( e \) during each year of the planning horizon of the with-project situations (monetary unit), or

\[
ABT1(ODE,pt,y) = 365 \times ADT1(ODE,pt1,y) \times DLTCM(ODE,pt,1,y) \quad \text{and}
\]

\[
TABT1(pt,y) = \sum_{ODE} ABT1(ODE,pt,y)
\]

4. Annual benefits related to traffic type \( t = 2 \) for each and all OD's of route \( e \) during each year of the planning horizon of the with-project situations (monetary unit), or

\[
ABT2(ODE,pt,y) = 365 \times ADT2(ODE,pt1,y) \times DLTCM(ODE,pt,2,y) \quad \text{and}
\]

\[
TABT2(pt,y) = \sum_{ODE} ABT2(ODE,pt,y)
\]

5. Annual benefits resulting from generated passenger traffic on each and all OD's of route \( e \) during each year of the planning horizon of the with-project situations (monetary unit), or

\[
ABGT1(ODE,pt,y) = \frac{365}{2} \times \left[ ADT1(ODE,pt,y) - ADT1(ODE,pt1,y) \right] \times DLTCM(ODE,pt,1,y) \quad \text{and}
\]

\[
TABGT1(pt,y) = \sum_{ODE} ABGT1(ODE,pt,y)
\]

6. Annual benefits resulting from diverted passenger traffic during each year of the planning horizon of the with-project situations (monetary unit), or

\[
ABDT3(pt,y) = (365 - ANDR) \sum_{ODn} ADT3(ODn,y) \times DLTCT(ODn,pt,3,y,1) + \sum_{ODn} ANDR \sum_{ODn} ADT3(ODn,y) \times DLTCT(ODn,pt,3,y,2)
\]

\[
+ ANDR \sum_{ODn} ADT3(ODn,y) \times DLTCT(ODn,pt,3,y,2)
\]
7. Annual benefits resulting from long distance generated passenger traffic during each year of the planning horizon of the with-project situations (monetary unit), or

\[ ABGT3(pt,y) = \frac{365}{2} \sum_{ODn} GT3(ODn,pt,y) \times DLTCM(ODn,pt,3,y) \]

8. Annual benefits resulting from diverted commodity traffic during each year of the planning horizon of the with-project situations (monetary unit), or

\[ ABDT4(pt,y) = (365 - ANDR) \sum_{ODn} ADT4(ODn,y) \times DLTTCT(ODn,pt,4,y,1) \]

\[ \quad + ANDR \sum_{ODn} ADT4(ODn,y) \times DLTTCT(ODn,pt,4,y,2) \]

Note that \( E(3,s=1) \) and \( E(3,s=2) \) are the groups of OD's of route n for which \( DLTTCT(ODn,pt,t=3,y,s) > 0 \); \( E(4,s=1) \) and \( E(4,s=2) \) are the groups of OD's of route n for which \( DLTTCT(ODn,pt,t=4,y,s) > 0 \).

65. Traffic Sub-Model

65.1 No additional inputs are required.

65.2 The calculations of this model are as follows:

1. For type 1 traffic:

\[ ADT1(ODE,pt,y) \] or average daily traffic of type \( t=1 \) on OD's of route \( e \) during each year of the planning horizon of the without- and with-project situations (passengers/day)

and

\[ TT1(p,y) = \sum_{ODE} ADT1(ODE,pt,y), \text{ or traffic of type } t=1 \text{ on route } e \]

\[ \quad \text{during each year of the planning horizon of the without- and with-project situations (passengers/day)} \]

2. For type 2 traffic:

\[ TT2(p,y) = \frac{TEXSU(p,y) + TIAI(pa,y)}{365} + ADT2(ODE,pt1,y) \]

or traffic of type \( t=2 \) during each year of the planning horizon of the without- and with-project situations (tons/day)

3. For type 3 traffic:

\[ TT3(p,y) = ADT03(pt,y) + TGT3(pt,y) \]
or traffic of type $t=3$ during each year of the planning horizon of the without- and with-project situations (passengers/day)

4. For type 4 traffic:
\[
TT4(p,y) = ADT04(pt,y)
\]
or traffic of type $t=4$ during each year of the planning horizon of the without- and with-project situations (tons/day)

5. Average daily traffic on the rural road considered during each year of the planning horizon of the without- and with-project situations (transport means/day), or
\[
ADTV(p,y,v) = [TT1(p,y) TT2(p,y) TT3(p,y) TT4(p,y)] \times M(pt,t,y,v)
\]

**ECONOMIC RETURN MODEL**

66. This model consists of three sub-models, i.e., Costs and Benefits, ER and NPV, and the Optimal Year. The inputs to these three sub-models are:

1. \( CCONS(p,y) = \) costs of improving or constructing the rural road, by year of the with-project situations (monetary unit)

2. \( CMAINT(p,y) = \) maintenance costs of the rural road (annual or periodic), by year of the without- and with-project situations (monetary unit)

3. \( CES(p,y) = \) costs of new techniques introduced to extension services, by year of the with-project situations (monetary unit)

4. \( CCREDD(p,y) = \) costs of making agricultural credit available, by year of the without- and with-project situations (monetary unit)

5. \( COTHR(p,y) = \) other costs (e.g., for irrigation works or silos), by year of the without- and with-project situations (monetary unit)

6. \( ELIIA = \) expected life of investments to improve an area (TICIA; year)

7. \( ELICA = \) expected life of investments to cultivate cultivable land (TICCA; year)

8. \( ELICNP = \) expected life of plantations (TICNP; year)

9. \( ELRR = \) expected life of rural road (year)

10. \( ELES = \) expected life of investments for extension services (CES; year)

11. \( ELCREDD = \) expected life of agricultural credit facilities (CCRED; year)
12. ELOTHR = expected life of other facilities (COTHR; year)
13. Seven replacement coefficients corresponding to Items 6 through 12 above
[RC(1), RC(2), RC(3), RC(4), RC(5), RC(6), RC(7)]

67. Costs and Benefits. the costs of investments to be considered in
the ER and NPV calculations are the aforementioned five costs and the follow-
ing three, which have already been computed in the AGRICULTURAL REVENUE MODEL,
viz, TICIA(p,y), TICCA(p,y) and TICNP(p,y). Naturally, costs of replacement
investments should be considered if these occur. The benefits to be considered
in the ER and NPV calculations are:

1. Benefits to farmers: DLRIFL(p,y) or DLREFL(p,y)
2. Benefits related to the agricultural development but not accruing to
the farmers: TCSC(p,y) and TTSU(p,y)
3. Benefits related to non-agricultural traffic:
   TABT1(pt,y)  
   TABCT1(pt,y)  
   TABT2(pt,y)  
   ABDT3(pt,y)  
   ABCT3(pt,y)  
   ABDT4(pt,y)
4. Other benefits [BOTHR(p,y)] to be introduced as an input to this model.
5. Salvage values: Certain agricultural investments can have an expected
life which exceeds that of the rural road. Therefore, the following salvage
values (monetary value) should be introduced as a benefit at the end of the
planning horizon, if this is the case:

Salvage value of TICIA(p,y), or
\[ SVIIA(p) = \sum_{y=1}^{h2} \left[ \frac{ELIIA - (h2 + 1 - y)}{ELIIA} \right] \times TICIA(p,y) \]

Salvage value of TICCA(p,y), or
\[ SVICA(p) = \sum_{y=1}^{h2} \left[ \frac{ELICA - (h2 + 1 - y)}{ELICA} \right] \times TICCA(p,y) \]

Salvage value of TICNP(p,y), or
\[ SVICNP(p) = \sum_{y=1}^{h2} \left[ \frac{ELICNP - (h2 + 1 - y)}{ELICNP} \right] \times TICNP(p,y) \]

Note that salvage values may also exist for investments related to CES, CCRED
and COTHR; the expected lives of these investments are, however, likely to
be smaller than the expected life of the rural road. Consequently, these
salvage values may be considered by introducing a salvage value for the replacement investments corresponding to CES, CCRED and COTH.

68. **ER and NPV.** Techniques for computing the ER and the NPV are well known and, therefore, not described here. An ER, NPV and optimal year may be computed for the following combinations:

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<th>Agricultural Investments</th>
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69. **Optimal Year.** The following symbols are introduced to facilitate the determination of the optimal year of road and agricultural investments, which are interdependent.

- \( yc \) = year of completing the road improvement (construction)
- \( \text{RHO}(1) \) = \( \text{RHO}(yc - 1, i, yc) \)
  \[ = c(yc - 1) + c[yc - 2(1 + i)] + ... + c(yc - y)(1 + i), y = 1 \]
  \( = \text{CCONS} \) during year \( yc - y, yc - (y - 1), ..., yc - 2 \) and \( yc - 1 \)
- \( \text{RHO}(2) \) = similar formula for CES
- \( \text{RHO}(3) \) = similar formula for CCRED
- \( \text{RHO}(4) \) = similar formula for COTH
- \( \text{RHO}(5) \) = similar formula for TICIA
- \( \text{RHO}(6) \) = similar formula for TICCA
- \( \text{THO}(7) \) = similar formula for TICNP
- \( D1 \) = ELRR
- \( D2 \) = ELES
- \( D3 \) = ELCCRED
- \( D4 \) = ELOTHR
- \( D5 \) = ELIIA
D6 = ELICA
D7 = ELICNP
i = opportunity cost of capital
Al(y) = total net benefits during year y, which are independent of yc
A2(y-yc) = total net benefits during year y which depend on (y-yc)

\[
S1 = \sum_{n=1}^{D1} \frac{A2(n)}{(1 + i)^n}
\]

RC(1) = replacement coefficient of rural road \((1 - \frac{\text{salvage value}}{\text{investment cost}})\)
RC(2) = replacement coefficient corresponding to CES
RC(3) = replacement coefficient corresponding to CCRED
RC(4) = replacement coefficient corresponding to COTHR
RC(5) = replacement coefficient corresponding to TICIA
RC(6) = replacement coefficient corresponding to TICCA
RC(7) = replacement coefficient corresponding to TICNP

\[
L(1) = \frac{1}{(1 + i)^{D1} - 1}
\]

\[
L(2) = \frac{1}{(1 + i)^{D2} - 1}
\]

\[
L(3) = \frac{1}{(1 + i)^{D3} - 1}
\]

\[
L(4) = \frac{1}{(1 + i)^{D4} - 1}
\]

\[
L(5) = \frac{1}{(1 + i)^{D5} - 1}
\]

\[
L(6) = \frac{1}{(1 + i)^{D6} - 1}
\]

\[
L(7) = \frac{1}{(1 + i)^{D7} - 1}
\]

The decision rule for determining the optimal year oy of the investment package can now be formulated as follows:
a. If \[ \sum_{j=1}^{7} \rho(j) \{1 + rc(j) l(j)\} - s_1 \] > 0,

\( o_y \) is the first year for which

\[ \sum_{j=1}^{7} \frac{a(t)}{\rho(j) \{1 + rc(j) l(j)\} - s_1} > 1 \]

b. If \[ \sum_{j=1}^{7} \rho(j) \{1 + rc(j) l(j)\} - s_1 \] < 0, and if \( a(t) > 0 \),

\( o_y = \text{as soon as possible} \)

c. If \[ \sum_{j=1}^{7} \rho(j) \{1 + rc(j) l(j)\} - s_1 \] < 0, and if \( a(t) < 0 \),

\( o_y = \text{infinite (never implementation)} \)
ANNEX 1

ECONOMIC ANALYSIS OF ROAD AND AGRICULTURAL INVESTMENTS

1. The following presentation pertains to the economic evaluation of an investment package consisting of a rural road improvement (construction) and complementary agricultural investments in its zone of influence. The prices on the local market of agricultural products produced in the rural road's zone of influence and transported to the local market, which are called the "local market prices", are assumed constant. In other words, the local market is the importing area and the road's zone of influence is the producing area. In addition to simplify the presentation non-agricultural traffic is ignored. Thus, all benefits to be had from the investment package accrue to farmers in the zone of influence and/or transporters of agricultural products over the rural road under consideration.

No Home Consumption

2. The benefits (B) accruing to farmers and transporters during a specific year of the situation where only one agricultural crop in the zone of influence is cultivated are graphically portrayed in Figure 1. This presentation as well as expression (1) for these benefits ignore home consumption in the with- and without-project situations.

---

1/ This form of presentation was suggested by Anandarup Ray. For extensive analysis along similar lines, see H. G. van der Tak and A. Ray, "The Economic Benefits of Road Transport Projects," World Bank Occasional Paper No. 13.
Figure 1

\[
B = (P_m q_2 - R_2) - (P_m q_1 - R_1) \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots
4. The following terms are introduced in order to divide E into $B_1$ or $B_2$, or benefits accruing to farmers and $B_2$, or benefits accruing to transporters:

- $k_1$, $k_2$ = economic costs of transporting over the rural road one ton of $q_1$ and one ton of $q_2$, respectively ($$/ton)
- $F_1$, $F_2$ = fare of transporting over the rural road one ton of $q_1$ and one ton $q_2$, respectively ($$/ton)

Thus, $K_1 = K_1 q_1$, $K_2 = K_2 q_1$, and

$$K_1 - K_2 = [F_1 q_1 - F_2 q_2] + [(F_2 q_2 - F_1 q_1) - (k_2 q_2 - k_1 q_1)]$$

The term $[F_1 q_1 - F_2 q_2]$ represents the difference between the farmer's transport bill in the without-project situation and his bill in the with-project situation, while $[(F_2 q_2 - F_1 q_1) - (k_2 q_2 - k_1 q_1)]$ represents the portion of transport savings accruing to transporters in the form of a higher profit.

Calling $(F_2 q_2 - F_1 q_1)$ the $\Delta$ transport revenues and $(k_2 q_2 - k_1 q_1)$ the $\Delta$ transport costs, we may also write:

$$K_1 - K_2 = -[\Delta \text{ transport revenues}] + [\Delta \text{ transport revenues} - \Delta \text{ transport costs}]$$

Defining

$P_1$, $P_2$ = farm-gate price of a specific agricultural product in the without- and with-project situation, respectively ($$/ton)

results in $P_m = P_2 + F_2 = P_1 + F_1$

Thus, the farm-gate price increases in the with-project situation by $(F_2 - F_1)$.

5. Expression (2) can now be rewritten as

$$B = (B_1) + (B_2) = [(P_2 + F_2) q_2 - C_2] - [(P_1 + F_1) q_1 - C_1] + [F_1 q_1 - F_2 q_2] + [(F_2 q_2 - F_1 q_1) - (k_2 q_2 - k_1 q_1)] =$$

$$= [(P_2 q_2 - C_2) - (P_1 q_1 - C_1)] + [(F_2 q_2 - F_1 q_1) - (k_2 q_2 - k_1 q_1)] \quad \ldots \ldots \ldots \ldots (3)$$
Home Consumption

6. Expressions (1), (2) and (3) ignore the home consumption in the without- and with-project situations (para. 2). Reference is made to Figure 2 in order to examine the effect of home consumption on $B_1$.

The symbols $H_1$, $H_2$, $Q_1$, $Q_2$, $P_1$ and $P_2$ in Figure 2 denote:

- $H_1$, $H_2$ = on-farm (home) consumption of the agricultural product with farm-gate price $P_1$ and $P_2$, respectively (tons)
- $Q_1$, $Q_2$ = production of the agricultural product with farm-gate price $P_1$ and $P_2$, respectively (tons)
- $P_1$, $P_2$ = as defined in para. 4

Note that $q_1 = Q_1 - H_1$ and $q_2 = Q_2 - H_2$.

The benefits accruing to farmers ($B_1$) during a specific year of the situation where one agricultural crop in the zone of influence is cultivated are represented by area ABCD of Figure 2. Assuming that AD and BC of the demand and supply curves of Figure 2 can be approximated by straight lines, gives:
area ABCD = \( (P_2 - P_1)Q_1 + \frac{1}{2} (P_2 - P_1) (Q_2 - Q_1) - [H_1(P_2 - P_1) - \frac{1}{2} (H_1 - H_2) (P_2 - P_1)] = (P_2 - P_1) (Q_1 - H_1) + \frac{1}{2} (P_2 - P_1) [(Q_2 - Q_1) + (H_1 - H_2)] \)

or, since \( q_1 = (Q_1 - H_1) \) and \( q_2 = (Q_2 - H_2) \),

area ABCD = \( (P_2 - P_1)q_1 + \frac{1}{2} (P_2 - P_1)[(q_2 - q_1) + (H_1 - H_2)] = \frac{1}{2} (P_2 - P_1) (q_2 - q_1) + (P_2 - P_1)q_1 = \frac{1}{2}(P_2 - P_1)(q_2 - q_1) \)

Defining \( \Delta P = (P_2 - P_1) \) and \( \Delta q = (q_2 - q_1) \) results in

\[ B_1 = \Delta P q_1 + \frac{1}{2} \Delta P \Delta q \] \hspace{1cm} (4)

Another way of expression \( B_1 \) is

\[ B_1 = \frac{1}{2} (F_1 - F_2)(q_2 + q_1) \] \hspace{1cm} (5)

since \( P_2 = (P_m - F_2) \) and \( P_1 = (P_m - F_1) \).

Expressions (4) and (5) are graphically represented by areas ABCD of Figure 3 and Figure 4, respectively. Note that areas ABED and BEC of Figure 3 correspond to \( \Delta P q_1 \) and \( \frac{1}{2} \Delta P \Delta q \) respectively; areas AECD and ECB of Figure 4 also correspond to \( \Delta P q_1 \) and \( \frac{1}{2} \Delta P \Delta q \) respectively.

---

**Figure 3**

**Figure 4**
7. Another way of taking into consideration the effect of home consumption on $B_1$ is as follows.

$$B_1 = (P_2 Q_2 - C_2) - (P_1 Q_1 - C_1) + (S_2 - S_1) \quad \ldots (6)$$

where $P_1, P_2, Q_1, Q_2, C_1$ and $C_2$ are as defined previously, and

$S_1, S_2 = \text{consumer surplus on home consumption in the without- and with-project situation, respectively (§)}$

Note that in Figure 2

area $FBMJ = P_2 Q_2 = \text{total income in the with-project situation}$
area $ECNJ = P_1 Q_1 = \text{total income in the without-project situation}$
area $GBMJ = \text{agricultural production costs in the with-project situation}$
area $GCNJ = \text{agricultural production costs in the without-project situation}$
area $OFA = S_2 = \text{consumer surplus in the with-project situation}$
area $OED = S_1 = \text{consumer surplus in the without-project situation}$
area $ADEF = -(S_2 - S_1) = \text{loss in consumer surplus}$

The term $-(S_2 - S_1)$ is determined as follows:

$$(S_2 - S_1) = -(\text{area } ADEF \text{ of Figure 2}) = -\Delta PH_2 + \frac{1}{2} \Delta PAH =$$

$$= -[(P_2 - P_1)H_2 + \frac{1}{2}(P_2 - P_1)(H_1 - H_2)]$$

$$= -(P_2 H_2 - P_1 H_2 - P_1 H_1 + P_1 H_1 + \frac{1}{2}(P_2 - P_1)(H_1 - H_2)]$$

$$= -(P_2 H_2 - P_1 H_1 + P_1 H_1 - P_1 H_2 + \frac{1}{2}(P_2 - P_1)(H_1 - H_2)]$$

$$= -(P_2 H_2 - P_1 H_1) - (P_1 H_1 - P_1 H_2) - \frac{1}{2}(P_2 - P_1)(H_1 - H_2)$$

$$= -(P_2 H_2 - P_1 H_1) - P_1(H_1 - H_2) - \frac{1}{2}(P_2 - P_1)(H_1 - H_2)$$

$$\ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (7)$$

Substituting expression (7) for $(S_2 - S_1)$ of expression (6) gives:

$$B_1 = (P_2 Q_2 - C_2) - (P_1 Q_1 - C_1) - (P_2 H_2 - P_1 H_1) -$$

$$- P_1(H_1 - H_2) - \frac{1}{2}(P_2 - P_1)(H_1 - H_2) =$$

$$= P_2 q_2 - P_1 q_1 - P_1(H_1 - H_2) - \frac{1}{2}(H_1 - H_2)(P_2 - P_1) -$$

$$- (C_2 - C_1) \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (8)$$
8. Expressions (4), (5) and (8) are different ways of evaluating $B_1$. Expression (8) is preferred if one wishes to examine the influence of changes in $C_1$ and $C_2$. In addition, a comparison between the first two terms of expression (3), which represent $B_1$, and expression (8) clearly shows the impact of home consumption in the without- and with-project situations on $B_1$. This impact is represented by $-P_1(H_1 - H_2) - \frac{1}{2}(H_1 - H_2)(P_2 - P_1)$. Thus, these terms should be added to expression (1) if the aforementioned impact is to be taken into consideration in this expression:

$$B = [(P_m q_2 - R_2) - (P_m q_1 - R_1)] + [-P_1(H_1 - H_2) - \frac{1}{2}(H_1 - H_2)(P_2 - P_1)] \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \li
10. Naturally, an expression for $B$ in terms of farm-gate prices is simply obtained by adding expression (8) to the last two terms of expression (3):

$$B = B_1 + B_2 = P_2 q_2 - P_1 q_1 - P_1 (H_1 - H_2) - \frac{1}{2} (H_1 - H_2)(P_2 - P_1) - (C_2 - C_1) + (P_2 q_2 - P_1 q_1) - (k_2 q_2 - k_1 q_1) \ldots (10)$$

Figure 6 is a graphical presentation of expression (10).
Note that in Figure 6:

Area ABCD represents the benefits accruing to farmers.

(Area AEFD - area ZXFD) represents the profit of transporters in the without-project situation.

(Area BEGC - area YZGC) represents the profit of transporters in the with-project situation.

(Area BEGC - area AEFD - area YZGC + area ZXFD) represents the benefits accruing to transporters.

Line YC is the same as line BC of Figure 3.
11. Assuming that the prices used in the illustration are efficiency prices and that salvage values are negligible, successive application of expression (9) or (10) to each crop of a zone of influence and the summation of the results give the total benefits of any year during the expected life of the investment project, if more than one crop is cultivated in a rural road's zone of influence.

12. The aforementioned discussion considers the one-to-one relationship between farm production and agricultural transport over the improved (constructed) rural road. Specifically, substitution along the compensated (i.e. excluding income effects) demand curve OD of Figure 2 will occur as the price of the agricultural product considered rises; less of this product will be consumed at home. Income effects can, of course, also be relevant. For instance, if the agricultural product is an important one in farm production, a price rise will increase farmers' income, which may result in increased "home" demand. In this case, the aforementioned demand curve OD will slope more steeply and the benefits evaluated by expression (9) or (10) will be underestimated.

13. Naturally, the demand curve OD may be more flat for an inferior product of the farm production and in this case expression (9) or (10) would overestimate the benefits B. The analysis of slopes of the compensated demand curve OD of Figure 2 is complex and time consuming. Generally, the costs of investments of a rural road improvement (construction) and complementary agricultural components do not warrant such an analysis.

14. Finally, it is noted that expression (9) corresponds to expression (1) of the text of the INTRODUCTION (p. 1). Expression (10) relates to expressions (2) and (3) of this text.
Beenhakker, Henri L.
Identification and appraisal of rural roads projects

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