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Article information
Article title
Supporting data for the integrated Agent-Based Modelling and Robust Optimization on food supply network design in COVID-19 pandemic.

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Keywords
Food Supply Chain; Rice Production; Uncertainty; Simulation; Optimization; Agent-Based Modelling; Robust Optimization

Abstract
This article presents the data as a support for “Designing a Food Supply Chain Strategy during COVID-19 Pandemic using an Integrated Agent-Based Modelling and Robust Optimization” [1]. An integration framework of Agent-Based Modelling (ABM) and Robust Optimization (RO) is proposed to address the food supply network development involving normal and pandemic condition issue regarding the actual food production data availability. In this article, the data associated with the integrated ABM simulation and RO are discussed. Particularly, this article provides the output rice production capacity data from the ABM simulation. This article also discusses how the output data from ABM simulation are processed to construct the polyhedral uncertainty set, which will later used by RO. By showing the output data from the ABM simulation and explaining how it is processed to be used in RO, other researchers and investigators could integrate their own ABM simulation model with RO to address their respective problems considering any uncertainty. Furthermore, the additional data needed for the optimization model are also included, which are mainly retrieved from the reports of government agencies.

Specifications table

| Subject                          | Management Science and Operations Research |
| Specific subject area | Agent-Based Modelling (ABM) and Robust Optimization (RO) for food supply network design involving normal and pandemic condition. |
|-----------------------|--------------------------------------------------------------------------------------------------|
| Type of data          | Tables and figures.                                                                               |
| How the data were acquired | The data are obtained from the ABM simulation, which gives the prediction on rice production volume given the normal and pandemic condition. Meanwhile, other input data for the optimization model are retrieved from government agencies. |
| Data format           | Raw and analyzed.                                                                                 |
| Description of data collection | There are two conditions applied within the ABM simulation: (1) normal condition and (2) pandemic condition. In other words, the impact of pandemic condition on the rice production volume is observed based on the output data from the simulation. |
| Data source location  | Institution: Universitas Padjadjaran  
City/Town/Region: Sumedang Regency  
Country: Indonesia |
| Data accessibility    | Data are within this article                                                                       |
| Related research article | A.L.H. Achmad, D. Chaerani, and T. Perdana. Designing a food supply chain strategy during COVID-19 pandemic using an integrated Agent-Based Modelling and Robust Optimization. Heliyon, p.e08448 (2021). https://doi.org/10.1016/j.heliyon.2021.e08448 |

Value of the data

- These data and descriptions of how it is processed are useful to give an example of ways to integrate ABM simulation with RO to address food supply chain problems considering uncertainties.
- These data and descriptions will be useful for other researchers and investigators who would like to optimize a certain problem in their food supply chain system considering uncertainties, particularly when the required data are hard to be collected or even unavailable at the moment.
- The data processing step provides a template for organizing any uncertain data in the problem to be used in RO.

Data description

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This article supports our original research article entitled “Designing a Food Supply Chain Strategy during COVID-19 Pandemic using an Integrated Agent-Based Modelling and Robust Optimization” [1]. While our original research article provides a high-level framework for integrating ABM and RO to address uncertain food supply chain problem with unlimited data availability and its’ result, this article explains how to combine such methods with related data used. Particularly, this article explains how to integrate ABM and RO by processing the outputs from ABM to be used as the input in RO. Subsequent paragraph gives a brief explanation of ABM, RO, and why do one need to consider integrating both methods in uncertain food supply chain problem with limited data availability.

RO is a method in optimization which able to handle uncertainties in optimization problem by assuming the uncertainties are exist in a convex hull uncertainty set. Hence, it requires uncertain dataset to be used to construct its' uncertainty set. When data availability is limited, ABM is one of the simulation methods that could be used to feed RO with the required data. ABM is chosen in our original research article as it has the unique ability to represent a system based on the actors and their behaviours, please see our original research article for high-level explanation of ABM & RO integration [1].

This section provides the output data of rice production volume from 100 repetitions of ABM simulation. The average rice production volume from 100 simulations are given in Table 1 and Table 2. As reflected in Table 1 and Table 2, there are two large rice production centers: Bekasi Regency and Bogor Regency. Meanwhile, the other regions are the metropolitan areas with smaller rice production capacity. The classic optimization techniques may use the average rice production volume from the 100 simulations. Nevertheless, the usage of average value is not accurate, particularly when the variations of the data are quite high. Therefore, RO is applied to handle the uncertainties of the data obtained from the ABM simulation. There are several studies incorporating types of uncertainties in the food supply chain problem as discussed by Kharisma and Tomy [3]. In this case, the uncertainties considered are the uncertain rice production volume generated from ABM simulation. The construction of polyhedral uncertainty set that gathers all the uncertainties of rice production volume is discussed in the next section, given the output data from the ABM simulation provided in this section.

Table 1: Average daily rice production volume (ton/day)

| i-th Simulation | Bekasi City | Bogor City | Depok City | Bekasi Regency | Bogor Regency |
|-----------------|-------------|------------|------------|----------------|---------------|
| 1               | 48.822      | 40.489     | 32.808     | 286.29         | 1060.277      |
| 2               | 24.216      | 129.67     | 46.478     | 346.178        | 1240.852      |
| 3               | 30.985      | 53.769     | 44.525     | 301.132        | 1107.796      |
| 4               | 135.789     | 22.783     | 42.833     | 243.978        | 1102.979      |
| 5               | 120.427     | 80.719     | 49.212     | 214.295        | 917.717       |
|   | 48.561 | 46.218 | 30.985 | 205.962 | 1120.165 |
|---|--------|--------|--------|---------|----------|
| 7 | 14.191 | 53.769 | 64.445 | 277.567 | 1215.074 |
| 8 | 128.238 | 51.035 | 100.508 | 366.618 | 879.051 |
| 9 | 10.025 | 73.818 | 42.833 | 286.29 | 871.369 |
|10 | 33.72 | 162.088 | 40.229 | 264.028 | 1011.064 |
|11 | 14.451 | 48.691 | 32.808 | 264.028 | 996.223 |
|12 | 135.92 | 57.414 | 18.878 | 290.587 | 1089.439 |
|13 | 25.517 | 2.734 | 47.78 | 289.805 | 954.692 |
|14 | 123.942 | 68.35 | 49.212 | 310.506 | 1026.427 |
|15 | 51.816 | 61.06 | 49.473 | 254.654 | 1017.964 |
|16 | 0.911 | 28.902 | 122.64 | 323.265 | 1020.829 |
|17 | 50.384 | 29.163 | 39.708 | 255.826 | 1055.46 |
|18 | 5.859 | 141.518 | 53.769 | 294.883 | 1013.147 |
|19 | 33.72 | 53.769 | 44.656 | 294.753 | 984.896 |
|20 | 30.335 | 74.99 | 2.343 | 368.311 | 1265.067 |
|21 | 30.985 | 63.663 | 4.557 | 327.04 | 1008.851 |
|22 | 61.06 | 69.131 | 92.566 | 270.016 | 905.74 |
|23 | 44.656 | 65.616 | 57.414 | 260.903 | 1006.377 |
|24 | 3.645 | 61.06 | 18.357 | 285.9 | 1025.906 |
|25 | 1.042 | 46.478 | 6.379 | 319.619 | 1050.773 |
|26 | 46.478 | 35.542 | 9.113 | 262.335 | 935.033 |
|27 | 75.771 | 35.542 | 31.246 | 243.327 | 938.027 |
|28 | 33.459 | 25.517 | 158.182 | 352.427 | 950.525 |
|29 | 35.542 | 44.656 | 5.598 | 293.581 | 903.787 |
|30 | 18.227 | 57.414 | 25.387 | 269.235 | 878.269 |
| i-th Simulation | Bekasi City | Bogor City | Depok City | Bekasi Regency | Bogor Regency |
|-----------------|-------------|------------|------------|----------------|---------------|
| 31              | 128.238     | 53.769     | 28.251     | 361.671        | 1057.673      |
| 32              | 25.517      | 33.72      | 23.825     | 248.795        | 920.061       |
| 33              | 59.888      | 69.262     | 3.645      | 269.756        | 996.353       |
| 34              | 57.284      | 54.68      | 19.138     | 212.342        | 930.606       |
| 35              | 3.645       | 129.54     | 43.093     | 281.343        | 901.834       |
| 36              | 6.379       | 64.705     | 64.705     | 297.877        | 1016.663      |
| 37              | 38.276      | 57.414     | 55.071     | 244.239        | 891.809       |
| 38              | 1.562       | 75.641     | 32.938     | 270.667        | 942.323       |
| 39              | 44.656      | 30.985     | 54.68      | 262.775        | 1171.069      |
| 40              | 69.262      | 34.631     | 34.761     | 305.949        | 1173.283      |
| 41              | 30.465      | 37.365     | 57.414     | 271.839        | 893.762       |
| 42              | 37.755      | 38.927     | 91.524     | 283.686        | 960.55        |
| 43              | 44.656      | 51.035     | 33.72      | 259.862        | 978.777       |
| 44              | 14.581      | 47.39      | 0          | 199.062        | 655.773       |
| 45              | 29.944      | 71.345     | 60.278     | 299.7          | 925.008       |
| 46              | 51.239      | 151.542    | 49.212     | 241.895        | 1029.031      |
| 47              | 6.51        | 38.146     | 65.616     | 237.859        | 864.99        |
| 48              | 41.01       | 54.29      | 0          | 325.348        | 1050.773      |
| 49              | 29.163      | 30.985     | 60.148     | 187.996        | 1133.704      |
| 50              | 29.163      | 39.057     | 0          | 256.216        | 1154.795      |
| 51              | 40.099      | 35.412     | 23.695     | 264.809        | 1173.283      |
| 52              | 10.025      | 49.212     | 54.68      | 253.352        | 982.552       |
| 53              | 20.049      | 48.431     | 38.276     | 233.563        | 900.142       |
|   |      |      |      |      |      |
|---|------|------|------|------|------|
|54 | 29.423 | 61.06 | 51.165 | 283.556 | 987.239 |
|55 | 18.617 | 64.705 | 14.581 | 316.104 | 875.275 |
|56 | 27.34  | 74.469 | 27.34  | 272.62  | 832.182 |
|57 | 50.124 | 51.946 | 64.705 | 269.105 | 966.93  |
|58 | 25.517 | 70.043 | 149.329 | 273.662 | 1153.624 |
|59 | 46.478 | 120.948 | 64.705 | 281.083 | 973.699 |
|60 | 6.379  | 65.616 | 0.911  | 291.107 | 1214.032 |
|61 | 40.099 | 7.291  | 124.072 | 264.158 | 957.816 |
|62 | 5.468  | 65.616 | 69.262 | 334.721 | 936.204 |
|63 | 22.523 | 39.188 | 52.858 | 319.098 | 868.375 |
|64 | 93.217 | 51.035 | 8.202  | 276.786 | 1089.7 |
|65 | 20.961 | 91.785 | 12.759 | 281.864 | 913.421 |
|66 | 41.01  | 48.301 | 20.961 | 243.848 | 1259.339 |
|67 | 36.454 | 11.717 | 25.778 | 246.061 | 977.735 |
|68 | 30.074 | 33.069 | 119.776 | 268.584 | 1131.621 |
|69 | 12.759 | 6.379  | 17.315 | 245.41  | 812.783 |
|70 | 29.163 | 64.705 | 37.365 | 296.706 | 914.983 |
|71 | 161.567 | 61.06 | 58.326 | 258.95  | 829.968 |
|72 | 125.374 | 129.15 | 24.606 | 229.787 | 987.109 |
|73 | 163.26 | 69.522 | 0.911  | 274.833 | 1116.129 |
|74 | 47.65  | 51.035 | 48.301 | 166.905 | 1123.159 |
|75 | 46.478 | 39.448 | 41.14  | 247.363 | 1201.274 |
|76 | 28.251 | 81.239 | 0      | 382.762 | 1026.817 |
|77 | 2.734  | 51.946 | 81.5   | 229.657 | 903.917 |
|78 | 0.911  | 73.818 | 0.911  | 253.482 | 922.925 |
Meanwhile, other input parameters for the optimization model are given in Table 3. Monthly rice demand and rice selling price data are provided in Table 4, which obtained from West Java in Figures published by Statistics of Jawa Barat [7; 8; 9; 10; 11; 12; 13; 14; 15; 16]. Fumigation cost (Rp6.34/kg) and spraying cost (Rp7.55/kg) are considered as rice handling costs [4]. Fumigation and spraying are carried out every three months and one month, respectively. Hence, the approximation of rice handling cost in each month is Rp9,663.33/kg. For the food hub development cost, the budget estimation is Rp250,000,000/unit/month [6].

### Table 3: continued

| i-th Simulation | Bekasi City | Bogor City | Depok City | Bekasi Regency | Bogor Regency |
|-----------------|-------------|------------|------------|----------------|---------------|
| 93              | 30.985      | 51.035     | 57.414     | 285.509        | 1300.349      |
| 94              | 14.581      | 54.81      | 0          | 197.5          | 699.647       |
| 95              | 102.2       | 61.06      | 42.963     | 275.615        | 744.693       |
| 96              | 51.946      | 102.2      | 18.227     | 240.593        | 988.411       |
| 97              | 71.084      | 51.946     | 1.823      | 254.393        | 1068.479      |
| 98              | 31.897      | 46.478     | 0          | 211.561        | 865.771       |
| 99              | 75.25       | 116.521    | 31.897     | 246.582        | 780.496       |
| 100             | 39.188      | 169.899    | 73.818     | 266.501        | 840.514       |

### Table 4: Monthly rice demand and selling price

| Rice demand (ton/month) | Bekasi City | Bogor City | Depok City | Bekasi Regency | Bogor Regency |
|-------------------------|-------------|------------|------------|----------------|---------------|
| 790.486                 | 295.723     | 628.294    | 978.951    | 1574.801       |
### Experimental design, materials and methods

This section discusses the data processing of the output data from ABM simulation to obtain the polyhedral uncertainty set. The data processing for the output data of Bekasi Regency is taken as an example. For the first step, the nominal data need to be defined, e.g., the average value of daily rice production volume in Bekasi Regency. One can calculate that the average value of daily rice production volume in Bekasi Regency is 273.628 tons/day. Once the nominal data is set, the next step is to set the uncertainty which disturbs the nominal data. In this case, the deviation of daily rice production volume becomes the uncertainty, which disrupts the nominal data as illustrated in Figure 1. The deviation of rice production volume is given in Table 5.

| Rice selling price (Million Rp/ton) | 11.582 | 11.066 | 11.722 | 11.582 | 11.066 |
|-------------------------------------|--------|--------|--------|--------|--------|

![Figure 1: The uncertainties of daily rice production volume in Bekasi Regency [1]](image-url)
Once the nominal data and the uncertainties are defined, then one can start constructing the polyhedral uncertainty set which covers all of the uncertainties as a convex hull. In other words, one should construct the smallest possible polyhedral set which contains all of the uncertainties. There are several convex hull algorithms developed [2; 17; 5]. Nevertheless, the general algorithm considering n-dimensional data by taking the projections of the data points on each of 2 dimensions combination is given below:

1. Considering the n-dimensional data, take any 2 dimensions combination as the projection.

2. Based on the 2 dimensions taken, pick any single dimension as the reference.

3. Given the 2-dimensional data projections, pick a single starting point from the data which has the smallest value on the reference dimension. If there are multiple data with the smallest value on the reference dimension, then pick the data which also has the smallest value on another dimension.

4. Pick a single termination point from the data which has the biggest value on the reference dimension. If there are multiple data which have the biggest value on the reference dimension, then pick the data which also has the biggest value on another dimension.

5. Create the lower inequality constraint of the data.

5.1. Given the starting point, calculate and record the slope between the starting point and the rest of other points of data.

5.2. Based on the retrieved slopes, select another point as the endpoint which gives the smallest slopes possible with the starting point. Then, create the inequality system given the starting point and endpoint.

5.3. Set the endpoint as the starting point (move to the next selected point).

5.4. Repeat the same step from 5.1. until the starting point has reached the termination point.

6. Create the upper inequality constraint of the data.

6.1. Given the starting point, calculate and record the slope between the starting point and the rest of other points of data.

6.2. Based on the retrieved slopes, select another point as the endpoint which gives the largest slopes possible with the starting point. Then, create the inequality system given the starting point and endpoint.

6.3. Set the endpoint as the starting point (move to the next selected point).

6.4. Repeat the same step from 6.1. until the starting point has reached the termination point.

7. The polyhedral uncertainty set based on the current 2-dimensional data is obtained. Repeat the same step from 1 until all of the 2-dimensional combinations are taken.
Table 5: Daily rice production volume deviation in Bekasi Regency

| i-th Simulation | Deviation | i-th Simulation | Deviation | i-th Simulation | Deviation | i-th Simulation | Deviation |
|-----------------|-----------|----------------|-----------|----------------|-----------|----------------|-----------|
| 1               | 12.662    | 26             | -11.293  | 51             | -8.819    | 76             | 109.134   |
| 2               | 72.55     | 27             | -30.301  | 52             | -20.276   | 77             | -43.971   |
| 3               | 27.504    | 28             | 78.799   | 53             | -40.065   | 78             | -20.146   |
| 4               | -29.65    | 29             | 19.953   | 54             | 9.928     | 79             | 10.579    |
| 5               | -59.333   | 30             | -4.393   | 55             | 42.476    | 80             | -5.955    |
| 6               | -67.666   | 31             | 88.043   | 56             | -1.008    | 81             | 28.155    |
| 7               | 3.94      | 32             | -24.833  | 57             | -4.523    | 82             | 23.531    |
| 8               | 92.99     | 33             | -3.872   | 58             | 0.034     | 83             | -23.531   |
| 9               | 12.662    | 34             | -61.286  | 59             | 7.455     | 84             | 32.451    |
| 10              | -9.6      | 35             | 7.715    | 60             | 17.479    | 85             | -13.636   |
| 11              | -9.6      | 36             | 24.249   | 61             | -9.47     | 86             | -49.96    |
| 12              | 16.959    | 37             | 29.389   | 62             | 61.093    | 87             | 12.793    |
| 13              | 16.178    | 38             | -2.961   | 63             | 45.471    | 88             | 11.36     |
| 14              | 36.878    | 39             | 9.147    | 64             | 3.158     | 89             | -31.212   |
| 15              | -18.974   | 40             | 32.321   | 65             | 8.236     | 90             | 17.089    |
| 16              | 49.637    | 41             | -1.789   | 66             | -29.78    | 91             | 34.014    |
| 17              | -17.802   | 42             | 10.059   | 67             | -27.567   | 92             | 13.053    |
| 18              | 21.255    | 43             | -13.766  | 68             | -5.044    | 93             | 11.881    |
| 19              | 21.125    | 44             | -74.566  | 69             | -28.218   | 94             | -76.128   |
| 20              | 94.683    | 45             | 26.072   | 70             | 23.078    | 95             | 1.987     |
| 21              | 53.412    | 46             | -31.733  | 71             | -14.678   | 96             | -33.035   |
| 22              | -3.612    | 47             | -35.769  | 72             | -43.841   | 97             | -19.234   |
| 23              | -12.725   | 48             | 51.72    | 73             | 1.206     | 98             | -62.067   |
Note that by using the above general algorithm with n-dimensional data, it is needed to define $C_n^m$ sub-polyhedral uncertainty set and combine it all together as a whole inequality system to obtain the n-dimensions polyhedral uncertainty set. In this case, the uncertain data are only 2-dimensional data. Let the $\zeta_1$ be the y-axis and t be the x-axis of Figure 1. Then, the obtained polyhedral uncertainty set, which defined as an inequality system, for the uncertain daily rice production volume in Bekasi Regency is given as follows:

\[
\begin{align*}
\zeta_1 &\leq 20.4400081 \cdot t - 11.68248 \\
\zeta_1 &\leq 1.3453084 \cdot t + 26.50691 \\
\zeta_1 &\leq -75.1202844 \cdot t + 1097.02521 \\
\zeta_1 &\geq -17.8361854 \cdot t + 26.59371 \\
\zeta_1 &\geq -0.2386837 \cdot t - 26.19880
\end{align*}
\]

and illustrated in Figure 2.

![Figure 2: Polyhedral uncertainty set for uncertain daily rice production volume in Bekasi Regency [1]](image)
Credit author statement

**Tomy Perdana**: Conceptualization, Methodology, Validation, Investigation, Resources, Writing-review and editing, Supervision, Project administration, and Funding acquisition; **Diah Chaerani**: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Writing-review and editing, Supervision; **Audi Luqmanul Hakim Achmad**: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Data Curation, Writing-original draft preparation, Writing-review and editing, Visualization.

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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