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Optimization of Inspection Routes Using Linear Programming & Nearest Neighbour at KJPP ANA & Rekan Gianyar

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Abstract

Inspection is the activity procedures of an appraiser identical with survey to the location of the object of assessment. Considering efficient KJPP ANA & Rekan Gianyar is important for determining the best route in order to reduce overtime. This research focused in optimizing the inspection case route to the location using Linear Programming (LP) and Nearest Neighbor (NN) for Traveling Salesman Problem cases. In addition, analyzing the comparison of the initial route and the new route with both methods after optimizing travel time to reduce overtime. This research combined set theory and distribution & transportation concepts in the optimization. The data in this research used primary data including initial route along with the coordinates and secondary includes company profiles, LP and NN algorithms collected through interviews, documentation and literature study. The collected data were processed with Microsoft Excel and Google Colaboratory software. The results found that the LP method minimized travel time savings by an average of 12%, while the NN method is 8%. The LP method minimized the average overtime and costs by 16 minutes (Rp. 13,000, -) while the NN method is 11 minutes (Rp. 9,000, -).

Keywords: Linear programming, Nearest neighbor, Route optimization, Traveling salesman problem

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INTRODUCTION

A contribution given by certain parties can influence the country's economy directly or indirectly at the same time (Mandagi & Ilat, 2015; Waskito & Sari, 2022). Public appraiser is one of the parties who has an indirect significant role to country's economy (Dio & Dermawan, 2023; Septo et al., 2022; Windyatri & Rayendra, 2023). It has a role in supporting a government's program in conducting a healthy and efficient economy due to its professionalism and independency (The Regulation of Finance Ministry, Number: 125/PMK.01/2008 related to Public Appraiser Service). The appraisal is closely defined as a working process of contributing an estimation and argument about economic value of a particular object in a certain period. A licensed enterprise used as an instance for public appraisers is called as the office public appraisal service or commonly known as KJPP or *Kantor Jasa Penilai Publik* in Indonesia.

KJPP Amin Nirwan Alfiantori and Rekan is one of public appraisal service office which has been exist more than 13 years in Indonesia. It has 25 public appraisers cooperated as Rekan at KJPP ANA, chained in all the regions in Indonesia supported by reliable appraisers. It is also registered by Indonesian Finance Ministry. KJPP ANA & Rekan has owned many experiences in appraising jobs whether those are asset appraisal or holdings for various needs and enterprises (Andriansyah et al., 2021; Chowdhury et al., 2021 Katagiri et al., 2016). In Indonesia, appraisers contribute their service by referencing the standard called as Indonesian Appraisal Standard and Indonesian Appraisal Ethic. Those are obligated by the public appraisers in conducting public appraisal.

The Indonesian Appraisal Standard 104 (SPI 104) related to an implementation in Indonesian Appraisal Ethic and Indonesian Appraisal Standard on the seventh edition-2018, section 3.2 states that "an appraisal investigation is the sufficient data collection process conducted by inspection, review, calculation, and analysis based on a particular appraisal object". Inspection is an activity of conducting an appraisal procedure towards a certain object done by an appraiser (Bulut & Erol, 2018). It is perceived as an logistic form in which logistic is one of components in a business needs goods, services, and information distribution in fulfilling consumers' needs (Baik & Valenzuela, 2020; Dyah, 2014). Conducting an inspection to the location is argued as the important consideration which is effective to determine the best route in a business (Ruffinelli & Barán, 2017; Mazin et al., 2017).

Inspection requires a duration for about 1 – 2 hours in once depending on the object condition and it needs 1 – 3 minutes for data comparison. The inspectional location is conducted in several points conducted by a resource without any repetition and turning back to the starting point (*depot*), that is KJPP ANA & Rekan Cabang Gianyar. The route determination is commonly conducted by the staff directly after receiving commission for inspecting the location. KJPP ANA & Rekan Gianyar have not owned a particular method in regulating the inspection route. It has been displayed in Table I about the route inspection cases in the location which is conducted around 2022 – 2023. Based on the interview conducted to the staff who conducts the inspection, the existing route emerges a problem related to the inspection lateness to the starting point which also causes over time work. Overtime is happening due to the lack of planning and route determination analysis in which it is counted from the initial until the ended time of work (Junaidi et al., 2020). The resulting overtime is an average of 2 hours. The company's loss due to delays is paid through overtime costs in which the company settles the overtime costs for 50,000 per hour. The rules and regulation which are adapted by the company has been relevant to the quality control system of KJPP ANA & Rekan and being approved by Indonesian Finance Ministry. In order to implement this regulation, the approved working hours are 8.30 – 17.30 WITA and 2 (two) absences for arriving and leaving and rest hours at 12.00 – 13.00 WITA. On an industrial scale, incorrect route selection will have an impact not only financially due to wasted fuel, but also non-financially resulting in customer disappointment and non-productive time at work which will result in losses for the company (Wibisono, 2018).

Route arrangements need to be reviewed in order to streamline employee journey time for inspection activities. Arranging the best route in a business that travels to various areas or points can be conducted by using technology. The best route provides minimized total distance, cost and time by visiting points only once and returning to the starting point in which it is perceived as Traveling Salesman Problem (TSP) (Peker et al., 2013; Taiwo et al., 2013). TSP can be a solution in optimizing the route through by the staffs in conducting an inspection.

Table I. Preliminary Data

Case	Date	Number of Appraisal Object Points	Number of Comparison Points	Total Travel Time (Hour)	Existing Working Hours (Hour)	Actual Working Hours (Hour)	Overtime (Hour)
1	11-Jun-22	3	9	3,23	9,03	8	1,03
2	23-Jun-22	3	8	4,67	10,43	8	2,43
3	24-Jun-22	5	6	4,28	12,98	8	4,98
4	14-Jul-22	4	3	2,77	9,87	8	1,87
5	22-Jul-22	3	7	4,30	10,03	8	2,03
6	9-Sep-22	5	2	1,59	10,16	8	2,16
7	2-Jan-23	5	9	1,15	9,95	8	1,95
8	20-Jun-23	5	2	1,48	10,05	8	2,05
9	2-Sep-23	4	9	2,10	9,40	8	1,40
10	15-Nov-23	3	2	2,62	8,19	8	0,19

Based on TSP, there is no method that can solve the problem efficiently (Negara et al., 2023). Complex TSP problems at NP-Hard (Non-deterministic polynomial-time hardness) level category can be easy to define but it is difficult to solve. Approximation method assists it to find good solutions in a short time rather than more definite methods (Zhou et al., 2015). In the Logistics Logic Book, TSP has several solutions approaches, namely; enumeration, linear programming, heuristics and metaheuristics (Wibisono, 2018). The enumeration or brute force approach has the characteristic of experimenting with all existing route combinations, then selecting the route producing the shortest total distance. Linear programming is an effort to solve TSP in finding a more structured optimal solution using linear program formulation in computing. Solving large-scale TSP can use a heuristic model with the priority of finding a solution being the speed of analysis. Meanwhile, metaheuristics have a higher level meaning that generalizes the scope of applications and models designed based on the problem being analyzed.

A study concerns on the problem of travelling *salesman problem* (TSP) using integer linear programming shows that an optimal output with the minimization distance percentage of 26.32%, 7.42% of time from the initial route (Paillin & Tupan, 2020). A similar method is also conducted which discovers a similar result indicating that the optimal solution to minimize the distance is 18.24% and time of initial route is 18.01%. (Paillin et al., 2020). Another study is conducted with the method of nearest neighbor presents that giving optimal route with the shortest distance which is 67 km by iterating it seven times or numbers of consumers (Fauzi & Sulistyono, 2022). It is also found that the nearest neighbor can contribute an optimal route with the shortest neighbor shows that there is a distance efficiency for about 50.09% from the starting route (Lusiani et al., 2023).

Data processing in Table I shows that the number of objective points is still on a small scale with a maximum of 14 consisting of assessment objects and comparison appraisal objects. Therefore, linear programming can be used to get optimal results. The calculations are accurate and take a short time (Yu et al., 2022). Comparing linear programming methods produces greater savings efficiency compared to nearest neighbor (Setiyawan, 2017). However, researchers also use the nearest neighbor heuristic method with its characteristics of being able to quickly produce solutions. Thus, a comparison of methods is conducted expecting the most optimal algorithm for the TSP problem.

Based on TSP related to the inspection case occurs at KJPP ANA & Rekan Gianyar in which its solution is using the assistance of Google Colab or Google Colaboratory. Therefore, this study is conducted based on the background which focuses on investigating the optimization of route inspection to the case location of Travelling Salesman Problem (TSP) uses Linear Programming and Nearest Neighbor at KJPP ANA & Rekan Gianyar.

METHOD

This study was quantitative research in which data processing was carried out using Microsoft Excel 2016, Google Maps, and Collaboratory software. It is quantitative research because it uses data that can be measured directly in the field, namely at KJPP ANA & Rekan Gianyar, and only focuses on inspection locations.

Data is a collection of information that is considered accurate and can be used as a basis for making conclusions in a study. Data were collected by researchers to be the basis for research. This research used the following data sources; a) primary data in this study were obtained independently by researchers from interviews with KJPP ANA & Rekan Gianyar. The primary data used were the initial route of the inspection and location coordinate data, b) secondary data in this study were obtained from the archives of the KJPP ANA & Rekan Gianyar, and the library, including company profile data, linear programming, and nearest neighbor algorithms through learning in the distribution and transportation course. The data collection methods in this study were conducted using the instruments; interview, documentation, literature review. The flow of this study was conducted based on the flow diagram in Figure 1 below.

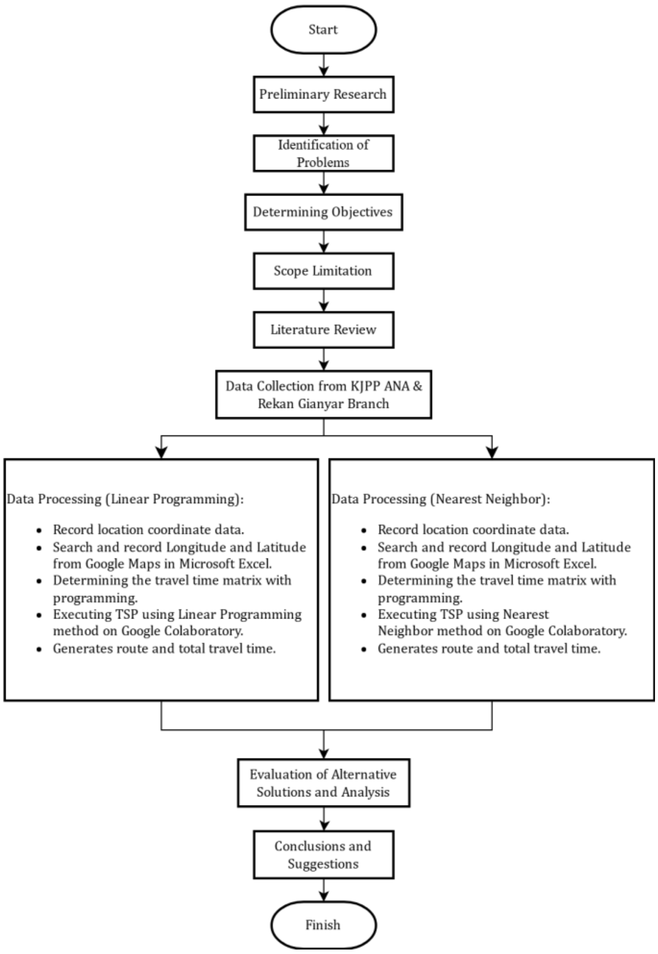

Figure 1. The Research Flow Diagram

RESULTS AND DISCUSSION

A. Description of the Appraisal Services Distribution System

The appraisal service distribution activities carried out by KJPP ANA & Rekan Gianyar cover the Bali Island area. The Traveling Salesman Problem cases used in this study are several cases that have a history of overtime indications in carrying out service distribution activities. The distribution system is carried out under the site inspection procedures implemented at the KJPP company.

B. Location Data and Request for Appraisal Services

The following is inspection location data consisting of appraisal objects and comparative data. Several cases selected in 2022 and 2023 are limited to 10 inspections in those years as shown in Table II.

Table II case 1-10

Code	Location	Coordinate	Latitude	Longitude
0	Depot (KJPP ANA & Rekan Gianyar)	8°38'10.9"S 115°15'43.0"E	-8.636323	115.2593506
1	Jalan Raya Besakih, Banjar Singarata	8°25'11.5"S 115°25'14.2"E	-8.419861	115.4103113
2	Jalan Surya Indah	8°25'08.2"S 115°25'29.2"E	-8.4189443	115.414478
3	Jalan Pedukuhan	8°24'36.4"S 115°25'07.3"E	-8.410111	115.4083946
4	Jalan Lingkungan Desa Rendang	8°26'10.6"S 115°25'29.4"E	-8.4362777	115.4145335
5	Jalan Raya Peringsari, Banjar Dinas Siladuni	8°25'57.2"S 115°27'52.4"E	-8.4325555	115.4542558
6	Jalan Raya Peringsari	8°25'49.2"S 115°27'38.8"E	-8.4303332	115.450478
7	Jalan Baledan	8°26'02.2"S 115°28'00.6"E	-8.4339444	115.4668333
8	Jalan Baledan	8°26'13.0"S 115°28'35.2"E	-8.4369443	115.4661446
9	Jalan Veteran (Jalur 11), Banjar Padangkerta	8°26'17.1"S 115°35'36.8"E	-8.4380832	115.5832558
10	Jalan Untung Surapati	8°26'14.6"S 115°35'36.7"E	-8.4373888	115.583228
11	Jalan Untung Surapati	8°26'21.6"S 115°35'44.3"E	-8.4393332	115.5853391
12	Jalan Raya Tirta Gangga	8°26'02.1"S 115°35'25.3"E	-8.4339166	115.5800613

Code	Location	Coordinate	Latitude	Longitude
0	Depot (KJPP ANA & Rekan Gianyar)	8°38'10.9"S 115°15'43.0"E	-8.636323	115.2593506
1	Jalan Mertasari Gang Kelana No.35	8°42'26.3"S 115°13'49.8"E	-8.7073055	115.2202002
2	Jalan Mertasari Gang Kelana	8°42'26.8"S 115°13'54.5"E	-8.7074443	115.2215058
3	Jalan Mertasari Gang Kelana	8°42'29.3"S 115°13'56.4"E	-8.7081388	115.2220335
4	Jalan Mertasari Gang Bambu III	8°42'30.2"S 115°13'51.3"E	-8.7083888	115.2206169
5	Jalan Gunung Kalimutu Gang V No. 7	8°40'05.6"S 115°11'57.7"E	-8.6682221	115.1890613
6	Jalan Gn. Kalimutu IV No. 3	8°40'07.1"S 115°11'53.9"E	-8,6686394	115,1981641
7	Jalan Gn. Kalimitu No. 19	8°40'09.1"S 115°11'53.8"E	-8,6692101	115,1957502
8	Jalan Lingkungan Dusun Penulisan	8°06'23.9"S 115°14'11.5"E	-8.1066388	115.226228
9	Jalan Lingkungan Desa Tunjung	8°06'38.7"S 115°14'35.3"E	-8.1107499	115.2328391
10	Jalan Lingkungan Desa Tunjung	8°06'23.0"S 115°14'31.8"E	-8.1063888	115.2318669
11	Jalan Lingkungan Desa Tunjung	8°06'26.0"S 115°14'58.8"E	-8.1072221	115.2393669

Code	Location	Coordinate	Latitude	Longitude
0	Depot (KJPP ANA & Rekan Gianyar)	8°38'10.9"S 115°15'43.0"E	-8.636323	115.2593506
1	Jalan Lingkungan Dusun Tonggak	8°06'54.4"S 115°14'25.7"E	-8.115111	115.2301724
2	Jalan Lingkungan Desa Tunjung	8°06'38.7"S 115°14'35.3"E	-8.1107499	115.2328391
3	Jalan Lingkungan Desa Tunjung	8°06'23.0"S 115°14'31.8"E	-8.1063888	115.2318669
4	Jalan Lingkungan Desa Tunjung	8°06'26.0"S 115°14'58.8"E	-8.1072221	115.2393669
5	Jalan Lingkungan Dusun Tonggak	8°05'51.7"S 115°14'45.4"E	-8.0976943	115.2356446
6	Jalan Lingkungan Dusun Penulisan	8°07'05.1"S 115°14'29.1"E	-8.1180832	115.2311169
7	Jalan Lingkungan Dusun Penulisan	8°06'55.4"S 115°14'35.9"E	-8.1153888	115.2330058
8	Desa Bukti, Kecamatan Kubutambahan	8°05'28.0"S 115°14'04.4"E	-8.091111	115.2242558
9	Jalan Lingkungan Desa Bukti	8°05'37.4"S 115°14'08.7"E	-8.0937221	115.2254502
10	Jalan Lingkungan Desa Bukti	8°05'40.1"S 115°13'45.3"E	-8.0944721	115.2189502
11	Jalan Lingkungan Desa Bukti	8°05'55.1"S 115°14'12.8"E	-8.0986388	115.2265891

Code	Location	Coordinate	Latitude	Longitude
0	Depot (KJPP ANA & Rekan Gianyar)	8°38'10.9"S 115°15'43.0"E	-8.636323	115.2593506
1	Perumahan Perdana Poh Gading Jimbaran Blok C No. 4	8°47'13.9"S 115°11'00.8"E	-8.7871943	115.1732558
2	Perumahan Perdana Poh Gading Jimbaran Blok B No. 2	8°47'15.0"S 115°11'01.2"E	-8.7874999	115.1733669
3	Jalan Bhineka Nusa Kauh I P.119	8°37'27.1"S 115°10'15.1"E	-8.6241943	115.1605613
4	Jalan Bhineka Nusa Kauh II	8°37'24.8"S 115°10'12.9"E	-8.6235555	115.1599502
5	Jalan Bhineka Nusa Kauh II	8°37'21.4"S 115°10'14.5"E	-8.622611	115.1603946
6	Jalan Bhineka Nusa Kauh II	8°37'19.5"S 115°10'16.1"E	-8.6220832	115.1608391
7	Kawasan Pecatu Indah Resort Blok Aster Kav. No. 17	8°48'18.8"S 115°07'32.8"E	-8.8052221	115.115478

Code	Location	Coordinate	Latitude	Longitude
0	Depot (KJPP ANA & Rekan Gianyar)	8°38'10.9"S 115°15'43.0"E	-8.636323	115.2593506
1	Perum Garden Villa Residence Jl. Bogenville Utama No.9	8°06'35.5"S 115°06'51.5"E	-8.109861	115.1040058
2	PERUM GARDEN VILLA	8°06'35.0"S 115°06'51.2"E	-8.1097221	115.1039224
3	PERUM GARDEN VILLA	8°06'34.4"S 115°06'50.3"E	-8.1095555	115.1036724
4	TANAH JL.P.KOMODO	8°06'22.3"S 115°06'09.5"E	-8.1061943	115.0923391
5	Perum Garden Villa Residence Jl. Bogenville II Kav.6	8°06'37.0"S 115°06'51.4"E	-8.1102777	115.103978
6	Jl Kemuda Blok II Nomor 11A, Desa Peguyangan Kangin	8°37'23.6"S 115°13'31.0"E	-8.6232221	115.214978
7	PERUM PERMATA ARSANDI	8°37'34.1"S 115°13'30.1"E	-8.6261388	115.214728
8	PERUM NINDYA INDAH SEROJA	8°37'53.6"S 115°13'38.0"E	-8.6315555	115.2169224
9	TANAH JL PERTULAKA	8°37'05.8"S 115°13'59.2"E	-8.6182777	115.2228113
10	Jalan Kaswari Gg. Jayaraga	8°37'20.4"S 115°14'15.2"E	-8.6223332	115.2272558

Code	Location	Coordinate	Latitude	Longitude
0	Depot (KJPP ANA & Rekan Gianyar)	8°38'10.9"S 115°15'43.0"E	-8.636323	115.2593506
1	Jalan Hayam Wuruk No. 240	8°39'50.5"S 115°14'24.9"E	-8.6640277	115.2299502
2	Perumahan Bukit Pratama, Jalan Gong Kebyar No. 25	8°48'02.5"S 115°10'49.0"E	-8.8006943	115.169978
3	Perumahan Bhuana Permata Hijau No. 21	8°39'33.8"S 115°11'23.5"E	-8.6593888	115.1795613
4	Perum. Bhuana Permata Hijau	8°39'34.1"S 115°11'21.7"E	-8.6594721	115.1790613
5	Jalan Surya Buana	8°40'02.1"S 115°11'12.6"E	-8.6672499	115.1765335
6	Jalan Buana Raya, Gang Puri Nusa Buana Ayu No. 5	8°39'39.0"S 115°11'13.2"E	-8.6608332	115.1767002
7	Jalan Buana Raya, Gang Puri Nusa Buana Ayu No. 5	8°39'39.0"S 115°11'13.7"E	-8.6608332	115.1768391

Code	Location	Coordinate	Latitude	Longitude
0	Depot (KJPP ANA & Rekan Gianyar)	8°38'10.9"S 115°15'43.0"E	-8.636323	115.2593506
1	Jalan Taman Wedasari IA, Desa Padangsambian Kaja	8°37'57.6"S 115°11'08.2"E	-8.6326667	115.1830362
2	Jalan Karangsari VII No. 20, Desa Padangsambian Kaja	8°37'55.1"S 115°11'23.2"E	-8.6319722	115.1872029
3	Jalan Taman Wedasari IA	8°37'57.8"S 115°11'07.9"E	-8.6327222	115.1829529
4	Jalan Taman Wedasari	8°37'55.9"S 115°11'10.4"E	-8.6321944	115.1836473
5	Jalan Mudu Taki, Perum Tegal Jaya	8°37'43.6"S 115°10'47.0"E	-8.6287778	115.1771473
6	Jalan Hanoman, Kelurahan Sempidi	8°36'18.8"S 115°10'59.9"E	-8.6052222	115.1807307
7	Jalan Raya Denpasar - Gilimanuk 18-16	8°36'38.5"S 115°11'30.4"E	-8.6106944	115.1892029
8	Jalan Raya Dalung	8°36'38.0"S 115°10'31.7"E	-8.6105556	115.1728973
9	Jalan Raya Abianbase	8°36'06.6"S 115°10'19.5"E	-8.6018333	115.1695084
10	Jalan Raya Abianbase, Badung	8°36'07.4"S 115°10'20.2"E	-8.6020556	115.1697029
11	Jalan Raya Munggu- Kapal No. 77 X	8°36'31.5"S 115°08'30.0"E	-8.60875	115.1390918
12	Jalan Raya Munggu - Kapal	8°36'31.2"S 115°08'32.0"E	-8.6086667	115.1396473
13	Jalan Raya Abianbase No. 148	8°36'02.2"S 115°10'23.1"E	-8.6006111	115.1705084
14	Jalan Raya Sempidi No. 43	8°35'54.6"S 115°11'11.4"E	-8.5985	115.1839251

Code	Location	Coordinate	Latitude	Longitude
0	Depot (KJPP ANA & Rekan Gianyar)	8°38'10.9"S 115°15'43.0"E	-8.636323	115.2593506
1	Jalan Padma Utara Gang Wisata No. 7	8°42'11.2"S 115°10'08.8"E	-8.703111	115.1588113
2	Jalan Padang Tegal III No. 1	8°37'14.0"S 115°10'15.9"E	-8.6205555	115.1607835
3	Jalan Bhineka Nusa Kauh II	8°37'24.8"S 115°10'12.9"E	-8.6235555	115.1599502
4	Jalan Bhineka Nusa Kauh II	8°37'19.5"S 115°10'16.1"E	-8.6220832	115.1608391
5	Jalan Muding Indah I, Kelurahan Kerobokan Kaja	8°38'46.7"S 115°10'52.3"E	-8.6463055	115.1708946
6	Jalan Raya Seminyak No. 13, Kelurahan Seminyak	8°41'43.9"S 115°10'05.2"E	-8.695528	115.168111
7	Jalan Dewi Saraswati III No. 7	8°41'08.0"S 115°10'26.2"E	-8.6855555	115.1636446

Code	Location	Coordinate	Latitude	Longitude
0	Depot (KJPP ANA & Rekan Gianyar)	8°38'10.9"S 115°15'43.0"E	-8.636323	115.2593506
1	Jl. Tratasan Pura Dalem Gg. Cemp. No.4	8°37'38.2"S 115°09'48.2"E	-8.6272564	115.1531106
2	Jl. Tratasan Pura Dalem	8°37'38.7"S 115°09'48.3"E	-8.6274166	115.1531169
3	Dalung, Kuta Utara	8°36'54.4"S 115°09'34.6"E	-8.615111	115.1493113
4	Jl. Beringin 83-86, Dalung	8°37'33.0"S 115°09'34.0"E	-8.6258332	115.1491446
5	Jl. Betaka, Dalung	8°37'32.2"S 115°09'40.6"E	-8.625611	115.150978
6	Perum Kori Agung Dawas No.29	8°37'46.9"S 115°09'56.0"E	-8.6296943	115.1552558
7	Gg. Seruni, Sanur	8°41'40.2"S 115°15'22.9"E	-8.6944999	115.2460613
8	Gg. Orchid 19-3, Sanur	8°41'11.9"S 115°15'25.4"E	-8.6866388	115.2467558
9	Sanur Kauh	8°41'16.4"S 115°15'03.4"E	-8.6878888	115.2406446
10	Jl. Gn. Sari 9-13	8°40'56.8"S 115°14'56.9"E	-8.6824443	115.2388391
11	Perum. Perdana Mumbul Cluster, Jalan Mumbul II No. 14,	8°47'52.2"S 115°11'53.6"E	-8.7978333	115.1956473
12	Perum Perdana Mumbul Cluster, Jalan mumbul II No.16	8°47'52.4"S 115°11'53.5"E	-8.7978889	115.1956195
13	Jl. Gunung Gede Pulasari	8°47'53.2"S 115°12'12.2"E	-8.7981111	115.200814

Code	Location	Coordinate	Latitude	Longitude
0	Depot (KJPP ANA & Rekan Gianyar)	8°38'10.9"S 115°15'43.0"E	-8.636323	115.2593506
1	Jl. Mawar, Belalang	8°35'16.5"S 115°06'31.1"E	-8.5879166	115.0983391
2	Sembung Gede	8°30'42.4"S 115°05'16.8"E	-8.5117777	115.0777002
3	Jl. Pulau Morotai No.34	8°40'42.5"S 115°12'33.6"E	-8.6784721	115.1990335
4	Jl. Pulau Ayu Selatan Gg. III 94-53	8°41'06.4"S 115°12'07.9"E	-8.685111	115.1918946
5	Mengwi, Cemagi	8°37'38.9"S 115°07'10.0"E	-8.6274721	115.1091446

C. Euclidean Distance

Mileage is the total distance traveled to all intended inspection locations (Paillin & Tupan, 2020). In this study, employee mileage inspected KJPP ANA & Rekan Gianyar to all locations, and distance between locations are obtained from Euclidean formula as follows.

$$d_{(ij)} = \sqrt{(xi - xj)^2 + (yi - yj)^2} \qquad (1)$$

Based on formula 1, points x and y are two points in euclidean space, which is a geometric space consisting of points that can be defined by their coordinates. However, the distance between points on Earth cannot be obtained using this formula. This is because latitude and longitude are not in geometric space. The distance between points on the Earth in kilometers can be obtained from the following formula below, although this formula provides a straight distance between location points.

$$d_{(ij)} = 111{,}189577 \times \text{degrees}\ (\cos^{-1}([\sin(\text{radians}(\text{latitude1})) \times \sin(\text{radians}(\text{latitude2}))] + [\cos(\text{radians}(\text{latitude1})) \times \cos(\text{radians}(\text{latitude2})) \times \cos(\text{radians}(\text{longitude1} - \text{longitude2}))]))$$

(2)

By,

$$\text{degrees} = \text{radians} \times 180/\text{phi}$$

$$\text{radians} = \text{degrees} \times \text{phi}/180$$

Based on formula 2, it uses latitude and longitude obtained from the Google Maps application by entering the coordinate points of the inspection location address. Calculations show that there is a small difference between manual calculations and the use of software which is caused by the precision that manual calculations lack due to rounding. In this study, the calculation of mileage is supported by the use of Google Colab software to make it easier to find the distance between points.

Euclidean distance is not used in optimization input, this is because this distance is a straight-line distance between points. Thus, if it is used in optimization, it will not show actual results. In fact, the distance taken by employees in carrying out inspections via roads connecting between locations is not a straight line resulting from Euclidean distance. The large difference between euclidean and actual distances indicates that euclidean distance cannot be used in optimization because the optimization results provide results that are not actual. Apart from that, optimization of distance cannot provide an overview of the overtime that occurs.

D. Travel Time

Travel time is the time required in the process of distributing services while traveling (Paillin & Tupan, 2020). In this study, a preliminary study has been conducted to determine the average speed obtained from the programming model, adjusted to the average speed of Google Maps as a reference of data input for the travel time matrix between points so that the results are close to actual. The average speed of the vehicles used is 30 km/hour. The formula for calculating travel time is as follows.

$$\text{Travel time} = \frac{d_{(ij)}}{v} \times 60 \text{ minutes} \quad (3)$$

Note:

$d_{(ij)}$: mileage (km)

v : vehicle speed (km/hour)

To conduct the distribution of appraisal services to produce a total time can be done by adding up the travel time, the duration of the inspection of the appraisal object about 1.5 hours, the inspection of comparative data for 2 minutes, and the rest time about 1 hour. In this study, travel time is calculated using formula 3 assisted by Google Colab software. Travel time is used as input in the optimization execution in Google Colab for setting routes using both Linear Programming and Nearest Neighbor methods. This is because travel time can provide an overview of the overtime that occurs in each case.

E. Initial Route of Service Distribution

The initial route for the service distribution is a route obtained directly from employees who conduct inspections at the location. Distance processing on this route is done from the depot, namely KJPP ANA & Rekan Gianyar, to all inspection locations and back to the depot. This study applies 10 cases selected from 2022-2023. The initial inspection routes for cases 1 to 10 are presented in Table III as follows.

Table III Initial inspection routes

Initial Inspection Routes		
Case	**Route**	**Travel Time (Minutes)**
1	[0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 - 11 - 12 - 0]	193,78
2	[0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 - 11 - 0]	280,02
3	[0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 - 11 - 0]	257,04
4	[0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 0]	166,64
5	[0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 - 0]	258,26
6	[0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 0]	95,88
7	[0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 - 11 - 12 - 13 - 14 - 0]	69,34
8	[0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 0]	88,98
9	[0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 - 11 - 12 - 13 - 0]	126,18
10	[0 - 1 - 2 - 3 - 4 - 5 - 0]	157,7

The initial inspection routes from the ten cases above are shown in the route, which is a sequence of location points (codes) equipped with travel times as the basis to compare improvements in the use of Linear Programming (LP) and Nearest Neighbor (NN) methods in the route optimization.

F. Route Setting by Linear Programming (LP) Method

The setting of the Traveling Salesman Problem route from inspection activities uses the Linear programming method assisted by Google Colab software. Briefly, the results of the settings using the LP method in these cases are presented in Table IV as follows.

Table IV. Linear Programming Method Inspection Routes

Linear Programming Method Inspection Routes		
Case	**Route**	**Travel Time (Minutes)**
1	[0 - 11 - 9 - 10 - 12 - 7 - 8 - 5 - 6 - 2 - 3 - 1 - 4 - 0]	187,82
2	[0 - 11 - 10 - 8 - 9 - 5 - 7 - 6 - 1 - 4 - 3 - 2 - 0]	277,24
3	[0 - 6 - 1 - 7 - 2 - 3 - 11 - 10 - 8 - 9 - 5 - 4 - 0]	247,24
4	[0 - 6 - 5 - 4 - 3 - 7 - 2 - 1 - 0]	115,86
5	[0 - 5 - 1 - 2 - 3 - 4 - 9 - 6 - 7 - 8 - 10 - 0]	256,9
6	[0 - 3 - 4 - 7 - 6 - 5 - 2 - 1 - 0]	92,2
7	[0 - 2 - 4 - 1 - 3 - 5 - 8 - 11 - 12 - 9 - 10 -13 - 14 - 6 - 7 - 0]	60,59
8	[0 - 2 - 4 - 3 - 5 - 7 - 1 - 6 - 0]	67,86
9	[0 - 3 - 4 - 5 - 1 - 2 - 6 - 11 - 12 - 13 - 7 - 8 - 9 - 10 - 0]	109,08
10	[0 - 2 - 1 - 5 - 4 - 3 - 0]	115,89

The use of the LP method in route optimization is shown above with the travel time after setting the LP method route. In the case of one sequential route from the depot with code 0 to the location with code 11 then to 9-10-12-7-8-5-6-4-2-1-3 until returning to the depot with a travel time of 187.82 minutes, as well as all cases that have been optimized. The use of the LP method in setting TSP routes tends to minimize all optimized cases. This exact method uses a linear programming formulation in computing. Thus, LP can solve problems that provide an optimal solution within its constraints (Fadhlurrahman & Binatari, 2019). Even though it requires a relatively longer time compared to other methods in formulation, the use of the LP method is effective in solving problems with a minimization objective function.

G. Route Setting by Nearest Neighbor (NN) Method

The setting of the Traveling Salesman Problem route for inspection activities applies the Nearest Neighbor method assisted by Google Colab software. Briefly, the results of the settings using the NN method in these cases are presented in Table V as follows.

Table V. Nearest Neighbor Method Inspection Routes

Nearest Neighbor Method Inspection Routes		
Case	**Route**	**Travel Time (Minutes)**
1	[0 - 4 - 1 - 2 - 3 - 6 - 5 - 7 - 8 - 12 - 10 - 9 - 11 - 0]	188,68
2	[0 - 6 - 7 - 5 - 1 - 4 - 2 - 3 - 9 - 10 - 8 - 11 - 0]	284,82
3	[0 - 6 - 1 - 7 - 2 - 3 - 4 - 5 - 11 - 9 - 8 - 10 - 0]	248,68
4	[0 - 3 - 4 - 5 - 6 - 1 - 2 - 7 - 0]	121,79
5	[0 - 10 - 9 - 6 - 7 - 8 - 5 - 1 - 2 - 3 - 4 - 0]	257,88
6	[0 - 1 - 3 - 4 - 7 - 6 - 5 - 2 - 0]	93,42
7	[0 - 2 - 4 - 1 - 3 - 5 - 8 - 10 - 9 - 13 - 6 - 14 - 7 - 12 - 11 - 0]	70,24
8	[0 - 5 - 3 - 4 - 2 - 7 - 6 - 1 - 0]	72,06
9	[0 - 10 - 9 - 8 - 7 - 6 - 2 - 1 - 5 - 4 - 3 - 11 - 12 - 13 - 0]	125,62
10	[0 - 3 - 4 - 5 - 1 - 2 - 0]	115,9

The use of the NN method in route optimization is shown above with the travel time after setting the NN method route. In the case of a sequential route from the depot with code 0 to the location with code 11 then to 1-2-3-4-6-5-8-7-12-10-9-11 until returning to the depot with a travel time of 188.68 minutes, as well as all cases that have been optimized. The use of the NN method provides less consistent results. It is indicated by the existence of two cases in cases 2 and 7 in which the results worsened with indications of an increase in travel time from the initial route after optimization. However, the other eight cases experience minimization of travel time based on the objective function, although the minimization is not more optimal than the results of the LP method. This incident shows that the linear programming method produces greater savings efficiency compared to the nearest neighbor (SETIYAWAN, 2017).

H. Comparative Analysis of Travel Time for The Initial Route and The New Route Using Linear Programming and Nearest Neighbor Method

To obtain the most optimal travel time for KJPP ANA & Rekan Gianyar company, a comparison is made for both methods, LP and NN. Table VI shows a comparison of the new route travel time results between the two methods.

Table VI. Comparison Of New Route Travel Time Results

Case	Initial	LP			NN		
		Result	Minimization	Percent Minimization	Result	Minimization	Percent Minimization
1	193,78	187,82	5,96	3,08%	188,68	5,10	2,63%
2	280,02	277,24	2,78	0,99%	284,82	-4,80	-1,71%
3	257,04	247,24	9,80	3,81%	248,68	8,36	3,25%
4	166,64	115,86	50,78	30,47%	121,79	44,85	26,91%
5	258,26	256,90	1,36	0,53%	257,88	0,38	0,15%
6	95,88	92,20	3,68	3,84%	93,42	2,46	2,57%
7	69,34	60,59	8,75	12,62%	70,24	-0,90	-1,30%
8	88,98	67,86	21,12	23,74%	72,06	16,92	19,02%
9	126,18	109,08	17,10	13,55%	125,62	0,56	0,44%
10	157,70	115,89	41,81	26,51%	115,90	41,80	26,51%
		Average Savings		**12%**	Average Savings		**8%**

Route settings using the LP method have significant results compared to the initial route travel time, showing that there is a minimization for all cases. It can be seen from case 1 that the travel time saving after using the LP method is 5.96 minutes or 3.08%. The LP method produces an average savings percentage of 12%.

Furthermore, the use of the NN method for setting routes has inconsistent results because in cases 2 and 7 there is an increase in travel time of 4.80 and 0.90, while this study has an objective function in the form of minimization. This incident occurs due to the NN method algorithm which has the characteristic that it starts with one point and then selects the closest point until all points are included in the route. In other words, this algorithm runs step by step without paying attention to the possible routes that can occur. Therefore, cases 2 and 7 cause negative travel time minimization. However, the other eight cases experience travel time minimization with a smaller percentage than the LP method. It is shown in case 1 that the travel time saving after using the NN method is 5.10 minutes or 2.63%. Only case 10 have equivalent results between the LP and NN methods. The NN method produces an average savings percentage of 8%.

In cases 1 to 10, several cases experience a slight minimization of travel time. This incident occurs because the optimized cases have routes that are quite optimal. As a result, if optimization is conducted, even though minimization occurs, the results are small.

From the explanation, it can be seen that the LP method is more effective in saving to achieve the minimization objective function compared to the NN method. To reduce overtime experienced by KJPP ANA & Rekan employees, it can be seen from the comparison between the initial route and the new route using both methods in Table VII below.

Table VII. Comparison Of The Initial Route And New Route

Case	Date	Total Travel Time (Initial)	Existing Working Hours (Initial)	Overtime (Hour)	Total Travel Time (LP)	Existing Working Hours (LP)	Overtime (Hour)	Execution Runtime (Second)	Total Travel Time (NN)	Existing Working Hours (NN)	Overtime (Hour)	Execution Runtime (Second)
1	11-Jun-22	3,23	9,03	1,03	3,13	8,93	0,93	2,39	3,14	8,94	0,94	0,01
2	23-Jun-22	4,67	10,43	2,43	4,62	10,38	2,38	3,02	4,75	10,51	2,51	1,49
3	24-Jun-22	4,28	12,98	4,98	4,12	12,82	4,82	0,64	4,14	12,84	4,84	0,55
4	14-Jul-22	2,77	9,87	1,87	1,93	9,03	1,03	1,09	2,03	9,13	1,13	0,38
5	22-Jul-22	4,30	10,03	2,03	4,28	10,01	2,01	4,11	4,30	10,03	2,03	1,06
6	9-Sep-22	1,59	10,16	2,16	1,54	10,11	2,11	1,44	1,56	10,13	2,13	0,33
7	2-Jan-23	1,15	9,95	1,95	1,01	9,81	1,81	2,52	1,17	9,97	1,97	0,34
8	20-Jun-23	1,48	10,05	2,05	1,13	9,70	1,70	1,58	1,20	9,77	1,77	1,15
9	2-Sep-23	2,10	9,40	1,4	1,82	9,12	1,12	3,74	2,09	9,39	1,39	1,24
10	15-Nov-23	2,62	8,19	0,19	1,93	7,50	-0,50	1,51	1,93	7,50	-0,50	0,01
Average				**2 Hours**			**1 Hour 44 Minutes**	**2,20**			**1 Hour 49 Minutes**	**0,65**

Based on Table VII, it is found that the average overtime on the initial route is about 2 hours, which has been optimized using the LP and NN methods. The LP method minimizes the average overtime by 16 minutes to 1 hour 44 minutes and the NN method minimizes the average overtime by 11 minutes to 1 hour 49 minutes. Thus, the use of LP and NN methods can be effective in solving TSP problems. However, the LP method is more optimal than the NN method.

Considering the small number of cases indicated by the maximum location of 14 points, solving small-scale TSP problems can be done by linear programming (Yu et al., 2022). Solving large-scale TSP is suitable using a heuristic model that prioritizes finding solutions quickly (Wibisono, 2018). Thus, optimization of the TSP case in this study using the LP method is optimal while the use of the NN method is less optimal. Table VII shows that the execution runtime of the LP method produces an average of 2.20 seconds whereas the NN method is 0.65 seconds proving that the NN method has a faster execution runtime than the LP method based on its characteristics.

From data analysis, optimal travel times will have a direct impact on the company, namely savings in overtime costs. The calculation of overtime cost savings can be shown in Table VIII below.

Table VIII. Overtime Cost Saving

Case	Date	Initial		LP		NN	
		Overtime (Hour)	Overtime Fees	Overtime (Hour)	Overtime Fees	Overtime (Hour)	Overtime Fees
1	11-Jun-22	1,03	Rp 51.500,00	0,93	Rp 46.516,67	0,94	Rp 47.233,33
2	23-Jun-22	2,43	Rp 121.500,00	2,38	Rp 119.033,33	2,51	Rp 125.350,00
3	24-Jun-22	4,98	Rp 249.000,00	4,82	Rp 241.033,33	4,84	Rp 242.233,33
4	14-Jul-22	1,87	Rp 93.500,00	1,03	Rp 51.550,00	1,13	Rp 56.491,67
5	22-Jul-22	2,03	Rp 101.500,00	2,01	Rp 100.583,33	2,03	Rp 101.400,00
6	9-Sep-22	2,16	Rp 108.000,00	2,11	Rp 105.333,33	2,13	Rp 106.350,00
7	2-Jan-23	1,95	Rp 97.500,00	1,81	Rp 90.491,67	1,97	Rp 98.533,33
8	20-Jun-23	2,05	Rp 102.500,00	1,70	Rp 85.050,00	1,77	Rp 88.550,00
9	2-Sep-23	1,40	Rp 70.000,00	1,12	Rp 55.900,00	1,39	Rp 69.683,33
10	15-Nov-23	0,19	Rp 9.500,00	-0,50	-Rp 24.925,00	-0,50	-Rp 24.916,67
Average		**2:00**	**Rp100.450,00**	**1:44**	**Rp87.056,67**	**1:49**	**Rp91.090,83**

Based on Table VIII, it is revealed that the average overtime on the initial route is 2 hours, causing losses to the company by paying overtime costs of Rp. 50.000,-/hour, which is about an average of Rp. 100.000,-. After optimization with the LP and NN methods, the LP method experiences savings of about Rp. 13.000,- to Rp. 87.000,- and the NN method experiences savings of about Rp. 9.000,- to Rp. 91.000,-. The LP method provides greater overtime cost savings commensurate with greater reductions in overtime as well.

As an effort to reduce overtime, companies can also pay more attention to making assignment plans and sorting work for each employee who carries out inspections (assessors) made by the job captain with a more adjusted distribution so that overtime does not occur. Using the method in this study when planning assignments can be a solution that can help reduce overtime. In addition, to reduce overtime, companies can easily determine optimal routes for employees and increase savings

CONCLUSION

Based on the results and discussion, several conclusions are made in optimizing the inspection case route to the location at KJPP ANA & Rekan Gianyar by using Linear programming and Nearest Neighbor Traveling Salesman Problem (TSP) cases. It shows that the LP method minimizes the average travel time saving by 12% and the NN method minimizes it by 8%. Optimization using the Linear programming method results in greater travel time savings compared to the Nearest neighbor method. In fact, using the Nearest neighbor method, two cases result in travel times that are greater than the initial route. The LP method results in a reduction in overtime from 2 hours to 1 hour 44 minutes and experience cost savings of Rp. 13.000 while the NN method decreases the average overtime from 2 hours to 1 hour 49 minutes and experiences cost savings of Rp. 9.000. The LP method minimizes an average overtime of 16 minutes and the NN method minimizes it of 11 minutes. It can be concluded that the Linear programming method has the greatest savings and it is appropriate to be used in the case of TSP at KJPP ANA & Rekan Gianyar. Further research is suggested to obtain more accurate results, it can be done to re-optimize using the Two-way Exchange Improvement Heuristic method.

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