DAFTAR PUSTAKA

Aldila, D. dkk., 2020. *A mathematical study on the spread of COVID-19 considering social distancing and rapid assessment: The case of Jakarta, Indonesia*. Chaos, Solitons & Fractals, 139, 110042.

Amalia, Lia dkk., 2020. *Analisis Gejala Klinis dan Peningkatan Kekebalan Tubuh untuk Mencegah Penyakit COVID-19*. Jambura Journal of Healt Sciences and Research Vol. 2, No 2 (2020).

BPS, 2022. Perilaku Masyarakat Pada Masa Pandemi COVID-19 Provinsi Sulawesi Selatan. Badan Pusat Statistik Provinsi Sulawesi Selatan

Bani, Alvioni dkk., 2021.*Stability Analysis of SCPUR Mathematical Model for The Spread of COVID-19*. J. Math. Comput. Sci. 11(2021) No. 4, 4082-4103.ISSN:1927-5307

Boyce W.E. & DiPrima, R., 2012. *Elementary Differential Equations*. 10th Edition penyunt. United state: John Willey &sons.

Braun, M., 1983. *Differential Equations and Their Applications*. Springer Verlag, New York.

Hairunisa, Nany, Husnun Amalia, 2020. *Review: Penyakit Virus Corona Baru 2019 (COVID-19).* Jurnal Biomedika dan Kesehatan Vol. 3 No. 2 Juni 2020

Haq, Abiyyu Didar dkk., 2021*. Faktor-faktor Terkait Tingkat Keparahan Infeksi Coronavirus Disease 2019 (COVID-19)*: Sebuah Kajian Literatur. Jurnal Ilmiah Mahasiswa kedokteran Vol. 9.1 Maret-Juli 2021. DOI: 10.53366/jimki.v9i1.338.

Joyner, Michael J dkk., 2020. *Safety Update: Covid-19 Convalescent Plasma in 20.000 Hospitalized Patients*. Mayo Foundation for Medical Education and Research, 95(9): 1888-1897.

Kemenkes, 2020. *13,2 Persen Pasien COVID-19 Yang Memiliki Penyakit Hipertensi* [Online]. Kementerian Kesehatan Republik Indonesia. Available at: https://www.kemkes.go.id/article/print/20101400002/13-2-persen-pasien-covid-19-yang-meninggal-memiliki-penyakit-hipertensi.html.

Kurniawan, E. Andry Dwi, Fatmawati, Dianpermatasari, Aprilia. 2021. Model Matematika SEAR dengan Memperhatikan Faktor Migrasi Terinfeksi untuk Kasus COVID-19 di Indonesia. Journal of Mathematics and Its Applications Vol. 18, No. 2, Nopember 2021, 142-153. DOI: http://dx.doi.org/ 10.12962/ limits.v18i2.7774

Lacy, dkk., 2020. COVID-19: *Postmortem Diagnostic and Biosafety Considerations*. The American Journal of Forensic Medicine and Pathology Volume 41 Issue 3-p 143-151.DOI: 10.1097/PAF.0000000000000567.

Lenhart, S., & Workman, J. T., 2007. *Optimal Control Applied to Biological Models*. London: Taylor & Francis Group.

Liu, Z dkk., 2020. *Predicting The Cumulative Number of Cases for The Covid-19 Epidemic in China from Early Data*. Mathematical Biosciences and Engineering 17(4), 3040-3051: DOI.10.3934/mbe.2020172.

Murrray, J., 2002. *Mathematical Biology I: AN Introduction. Third Edition*. Berlin Heidelberg: Spring.

Musa, S.S. dkk., 2021. Mathematical Modelling of COVID-19 Epidemic with Effect of Awareness Programs. Infectious Disease Modelling. DOI: https://doi.org/10.1016/j.idm.2021.01.012.

Naidu, S. D., 2002. *Optimal Control System*. USA: CRC Press LLC.

Nasruddin dan Haq, dkk., 2020. *Pembatasan Sosial Berskala Besar (PSBB) dan masyarakat Berpenghasilan Rendah*. Clinical and Experimental Medicine.DOI 10.15408/sjsbs.v717.15569.

Nisardi, Muhammad Rifki dkk., (2022). *Fractional Mathematical Model of COVID-19 with Quarantine*. Indonesian Journal of Pure and Applied Mathematics Vol. 4, No. 1. DOI: 10.15408/inprime.v4i1.23719.

Satyakti, Yayan, 2021. Predicting COVID-19 Unreported Case From Space. Jurnal Kajian Kebijakan Penerbangan dan Anariksa Vol. 2 No. 1.DOI: 10.30536/jkkpa.v2n1.5.

Sumadikarya, I. K., 2003. *Severe Acute Respiratory Syndrome (SARS)*. *Meditek*.

Sun, Meng Yao dkk., 2020. *A Potentially Effective Treatment for COVID-19: A Sistematic Review and Meta-analysis of Convalescent Plasme Therapy in Treating Severe Infectous Disease.International Journal of Infectious Diseases.*DOI https/doi.org/10.1016/ j.ijid.2020.06.107.

Sutaryo dkk., 2020. *Buku Praktis Penyakit Virus Corona 19 (Covid-19)*. Yogyakarta: Gajah Mada University Press dan Anggota IKAP dan APPTI.

Tang, B., Wang, X., Li, Q., Bragazzi, N. L., Tang, S., Xiao, Y., & Wu, J. (2020). Estimation of the transmission risk of the 2019-nCoV and its implication for public health interventions. Journal of Clinical Medicine, 9, 462. https://doi.org/10.3390/jcm9020462

Wiggins, S., 1990. *Introduction To Applied Nonlinear Dynamical Systems And Chaos*.Second Edition Penyunt. New York: Springer.

Word Health Organization (WHO), 2020. *Novel Coronavirus 2019*. [internet]Available from:https://www.who.int/emergencies/diseases/ novel-coronavirus-2019 [Diakses 13 September 2021].

Yanti, Etri dkk., 2020. *Pneumonia Covid-19, Diagnosis dan Penatalaksanaan di Indonesia*. Journal Abdimas Saintika 2(1):2715-4424: Perhimpunan Dokter Paru Indonesia Jakarta.

Zuin, M. dkk., 2021. *Viral Load Difference between Symptomatic and Asymptomatic COVID-19 Patients: Sistematic Review and Meta-Analysis*. National library of Medicine, *13*(3), 645-653;

LAMPIRAN 1

$$c=-\Big(\big(\mu+(-q+1)\,\omega+\alpha_1 q+\varepsilon\big)N\Big(-\mu^2+\big(-\omega-\delta-\sigma+\big((\rho-1)\,u_1-\rho+1\big)\beta\big)\mu+\big(-\delta-\sigma+\big((\rho-1)\,u_1-\rho+1\big)\beta\big)\,\omega+\delta_2\,\beta\,(\rho-1)\,(u_1-1)\Big)\big(-\mu-\omega+(u_2-1)\,\alpha_2\big)\mu\,(\mu+\gamma 1)\Big)\Big/\Big(\Big(\mu^4+\big((-q+2)\,\omega+(-u_2+1)\,\alpha_2+\alpha_1 q+\varepsilon+\delta+\sigma+\gamma 1\big)\mu^3+\Big(-(u_2-1)\,\big((-q+1)\,\omega+\alpha_1 q+\varepsilon+\delta+\sigma+\gamma 1\big)\alpha_2+(-q+1)\,\omega^2+\Big((-q+2)\,\gamma 1+\big(\alpha_1-\delta-\sigma\big)q+\varepsilon+2\,\delta+2\,\sigma\Big)\omega+\big(\alpha_1 q+\delta+\varepsilon\big)\gamma 1+(\delta+\sigma)\,\big(\alpha_1 q+\varepsilon\big)\Big)\mu^2+\Big(-(u_2-1)\,\Big(-(\delta+\sigma+\gamma 1)\,(q-1)\,\omega+\big(\alpha_1 q+\delta+\varepsilon-\delta_3\big)\gamma 1+(\delta+\sigma)\,\big(\alpha_1 q+\varepsilon\big)\Big)\alpha_2-(\delta+\sigma+\gamma 1)\,(q-1)\,\omega^2+\Big(\Big(\big(\alpha_1-\delta\big)q+\varepsilon+2\,\delta\Big)\gamma 1+(\delta+\sigma)\,\big(\alpha_1 q+\varepsilon\big)\Big)\omega+\Big(-\alpha_1\,\big(\delta_1-\delta\big)q+\delta\,\varepsilon\Big)\gamma 1\Big)\mu+\Big(\Big(-(q-1)\,\big(\delta_3-\delta\big)\,\omega+\big(\delta_1+\delta_3-\delta\big)\,\big(\alpha_1 q+\varepsilon\big)\Big)(u_2-1)\,\alpha_2+\Big(-\delta\,(q-1)\,\omega-\alpha_1\,\big(\delta_1-\delta\big)q+\delta\,\varepsilon\Big)\omega\Big)\gamma 1\Big)\big(\delta_2+\mu+\omega\big)\beta\,(u_1-1)\,(\rho-1)\Big)$$

$$p=-\Big(\big(-\mu-\omega+(u_2-1)\,\alpha_2\big)\delta_1\,\mu\,N\Big(-\mu^2+\big(-\omega-\delta-\sigma+\big((\rho-1)\,u_1-\rho+1\big)\beta\big)\mu+\big(-\delta-\sigma+\big((\rho-1)\,u_1-\rho+1\big)\beta\big)\,\omega+\delta_2\,\beta\,(\rho-1)\,(u_1-1)\Big)(\mu+\gamma 1)\Big)\Big/\Big(\Big(\mu^4+\big((-q+2)\,\omega+(-u_2+1)\,\alpha_2+q\,\alpha_1+\varepsilon+\delta+\sigma+\gamma 1\big)\mu^3+\Big(-(u_2-1)\,\big((-q+1)\,\omega+q\,\alpha_1+\varepsilon+\delta+\sigma+\gamma 1\big)\alpha_2+(-q+1)\,\omega^2+\Big((-q+2)\,\gamma 1+\big(\alpha_1-\delta-\sigma\big)q+\varepsilon+2\,\delta+2\,\sigma\Big)\omega+\big(q\,\alpha_1+\delta+\varepsilon\big)\gamma 1+(\delta+\sigma)\,\big(q\,\alpha_1+\varepsilon\big)\Big)\mu^2+\Big(-(u_2-1)\,\Big(-(\delta+\sigma+\gamma 1)\,(q-1)\,\omega+\big(q\,\alpha_1+\delta+\varepsilon-\delta_3\big)\gamma 1+(\delta+\sigma)\,\big(q\,\alpha_1+\varepsilon\big)\Big)\alpha_2-(\delta+\sigma+\gamma 1)\,(q-1)\,\omega^2+\Big(\Big(\big(\alpha_1-\delta\big)q+\varepsilon+2\,\delta\Big)\gamma 1+(\delta+\sigma)\,\big(q\,\alpha_1+\varepsilon\big)\Big)\omega+\Big(-\alpha_1\,\big(\delta_1-\delta\big)q+\delta\,\varepsilon\Big)\gamma 1\Big)\mu+\Big((u_2-1)\,\Big(-(q-1)\,\big(\delta_3-\delta\big)\,\omega+\big(\delta_1+\delta_3-\delta\big)\,\big(q\,\alpha_1+\varepsilon\big)\Big)\alpha_2+\Big(-\delta\,(q-1)\,\omega-\alpha_1\,\big(\delta_1-\delta\big)q+\delta\,\varepsilon\Big)\omega\Big)\gamma 1\Big)(u_1-1)\,(\rho-1)\,\big(\delta_2+\mu+\omega\big)\beta\Big)$$

$$v=\Big(\big(\delta_3\,\mu-\delta_3\,(q-1)\,\omega+\alpha_1\,\delta_3\,q+\varepsilon\,\big(\delta_1+\delta_3\big)\big)\Big(-\mu^2+\big(-\omega+\big((\rho-1)\,u_1-\rho+1\big)\beta-\delta-\sigma\big)\mu+\Big(\big((\rho-1)\,u_1-\rho+1\big)\beta-\delta-\sigma\Big)\omega+\delta_2\,\beta\,(\rho-1)\,(u_1-1)\Big)(\mu+\gamma 1)\,\mu\,N\Big)\Big/\Big(\big(\delta_2+\mu+\omega\big)\Big(\mu^4+\big((-q+2)\,\omega+\gamma 1+\alpha_1 q+\varepsilon+(-u_2+1)\,\alpha_2+\delta+\sigma\big)\mu^3+\Big((-q+1)\,\omega^2+\Big((q-1)\,(u_2-1)\,\alpha_2+(-q+2)\,\gamma 1+\big(\alpha_1-\delta-\sigma\big)q+\varepsilon+2\,\delta+2\,\sigma\Big)\omega-\big(\alpha_1 q+\delta+\gamma 1+\sigma+\varepsilon\big)(u_2-1)\,\alpha_2+\big(\alpha_1 q+\delta+\varepsilon\big)\gamma 1+(\delta+\sigma)\,\big(\alpha_1 q+\varepsilon\big)\Big)\mu^2+\Big(-(\delta+\sigma+\gamma 1)\,(q-1)\,\omega^2+\Big((\delta+\sigma+\gamma 1)\,(q-1)\,(u_2-1)\,\alpha_2+\Big(\big(\alpha_1-\delta\big)q+\varepsilon+2\,\delta\Big)\gamma 1+(\delta+\sigma)\,\big(\alpha_1 q+\varepsilon\big)\Big)\omega-(u_2-1)\,\Big(\big(\alpha_1 q+\delta+\varepsilon-\delta_3\big)\gamma 1+(\delta+\sigma)\,\big(\alpha_1 q+\varepsilon\big)\Big)\alpha_2+\Big(-\alpha_1\,\big(\delta_1-\delta\big)q+\varepsilon\,\delta\Big)\gamma 1\Big)\mu+\Big(-\delta\,(q-1)\,\omega^2+\Big(-(q-1)\,\big(\delta_3-\delta\big)\,(u_2-1)\,\alpha_2-\alpha_1\,\big(\delta_1-\delta\big)q+\varepsilon\,\delta\Big)\omega+\alpha_2\,\big(\delta_1+\delta_3-\delta\big)\,\big(\alpha_1 q+\varepsilon\big)\,(u_2-1)\Big)\gamma 1\Big)(\rho-1)\,\beta\,(u_1-1)\Big)$$

$$u=-\Big(\big(-\mu-\omega+(u_2-1)\,\alpha_2\big)\big(\mu+(-q+1)\,\omega+\alpha_1 q+\varepsilon\big)\Big(-\mu^2+\big(-\omega+\big((\rho-1)\,u_1-\rho+1\big)\beta-\delta-\sigma\big)\mu+\Big(\big((\rho-1)\,u_1-\rho+1\big)\beta-\delta-\sigma\Big)\omega+\delta_2\,\beta\,(\rho-1)\,(u_1-1)\Big)\delta_2\,(\mu+\gamma 1)\,\mu\,N\Big)\Big/\Big(\big(\delta_2+\mu+\omega\big)\Big(\mu^4+\big((-q+2)\,\omega+\gamma 1+\alpha_1 q+\varepsilon+(-u_2+1)\,\alpha_2+\delta+\sigma\big)\mu^3+\Big((-q+1)\,\omega^2+\Big((q-1)\,(u_2-1)\,\alpha_2+(-q+2)\,\gamma 1+\big(\alpha_1-\delta-\sigma\big)q+\varepsilon+2\,\delta+2\,\sigma\Big)\omega-\big(\alpha_1 q+\delta+\gamma 1+\sigma+\varepsilon\big)(u_2-1)\,\alpha_2+\big(\alpha_1 q+\delta+\varepsilon\big)\gamma 1+(\delta+\sigma)\,\big(\alpha_1 q+\varepsilon\big)\Big)\mu^2+\Big(-(\delta+\sigma+\gamma 1)\,(q-1)\,\omega^2+\Big((\delta+\sigma+\gamma 1)\,(q-1)\,(u_2-1)\,\alpha_2+\Big(\big(\alpha_1-\delta\big)q+\varepsilon+2\,\delta\Big)\gamma 1+(\delta+\sigma)\,\big(\alpha_1 q+\varepsilon\big)\Big)\omega-(u_2-1)\,\Big(\big(\alpha_1 q+\delta+\varepsilon-\delta_3\big)\gamma 1+(\delta+\sigma)\,\big(\alpha_1 q+\varepsilon\big)\Big)\alpha_2+\Big(-\alpha_1\,\big(\delta_1-\delta\big)q+\varepsilon\,\delta\Big)\gamma 1\Big)\mu+\Big(-\delta\,(q-1)\,\omega^2+\Big(-(q-1)\,\big(\delta_3-\delta\big)\,(u_2-1)\,\alpha_2-\alpha_1\,\big(\delta_1-\delta\big)q+\varepsilon\,\delta\Big)\omega+\alpha_2\,\big(\delta_1+\delta_3-\delta\big)\,\big(\alpha_1 q+\varepsilon\big)\,(u_2-1)\Big)\gamma 1\Big)(\mu+\omega)\,(\rho-1)\,\beta\,(u_1-1)\Big)$$

$$r=-\Big(\Big(-\mu^2+\big(-\omega+\big((\rho-1)\,u_1-\rho+1\big)\beta-\delta-\sigma\big)\mu+\big((\rho-1)\,(u_1-1)\,\beta-\delta-\sigma\big)\,\omega+\delta_2\,\beta\,(\rho-1)\,(u_1-1)\Big)\Big(\Big(\big(\delta_3+\sigma\big)\mu-(q-1)\,\big(\delta_3+\sigma\big)\,\omega+\big(\delta_1+\delta_3+\sigma\big)\,\big(\alpha_1 q+\varepsilon\big)\Big)(u_2-1)\,\alpha_2-\Big(\mu\,\sigma-\sigma\,(q-1)\,\omega+\big(\alpha_1 q+\varepsilon\big)\sigma+\alpha_1\,\delta_1\,q\Big)(\mu+\omega)\Big)\mu\,N\Big)\Big/\Big(\beta\,(\rho-1)\,(u_1-1)\,\Big(\Big(-\mu^3+\big((q-1)\,\omega-\alpha_1 q-\varepsilon-\delta-\sigma-\gamma 1\big)\mu^2+\Big((\delta+\sigma+\gamma 1)\,(q-1)\,\omega+\big(-\alpha_1 q-\varepsilon\big)\sigma-\alpha_1\,(\delta+\gamma 1)\,q+\gamma 1\,\delta_3+(-\delta-\gamma 1)\,\varepsilon-\delta\,\gamma 1\Big)\mu+\gamma 1\,\Big(-(q-1)\,\big(\delta_3-\delta\big)\,\omega+\big(\delta_1+\delta_3-\delta\big)\,\big(\alpha_1 q+\varepsilon\big)\Big)\Big)(u_2-1)\,\alpha_2+\Big(\mu^3+\big((-q+1)\,\omega+\alpha_1 q+\varepsilon+\delta+\sigma+\gamma 1\big)\mu^2+\Big(-(\delta+\sigma+\gamma 1)\,(q-1)\,\omega+\big(\alpha_1 q+\varepsilon\big)\sigma+\alpha_1\,(\delta+\gamma 1)\,q+(\delta+\gamma 1)\,\varepsilon+\delta\,\gamma 1\Big)\mu+\gamma 1\,\Big(-\delta\,(q-1)\,\omega-\alpha_1\,\big(\delta_1-\delta\big)q+\varepsilon\,\delta\Big)\Big)(\mu+\omega)\Big)\big(\delta_2+\mu+\omega\big)\Big)$$

LAMPIRAN 2

> *restart* :

>

> *with(linalg)* : *with(plots)* : *with(DEtools)* :

>

> *with(plots)* : *with(linalg)* : *with(VectorCalculus)* :

> $\#\mu := 0.0107;\ \gamma 1 := 0.01; \sigma := 0.17; q := 0.96;\ \alpha_1 := 0.1164;\ \alpha_2 := 0.40;\ \omega := 0.025;\ \varepsilon := 0.169055;\ \rho := 0.7;\ \beta := 0.99;\ u_1 := 0;\ u_2 := 0;\ \delta_1 := 0.1259;\ \delta_2 := 0.04;\ \delta_3 := 0.13206;\ N := 1500000;$

> $P1 := \mu \cdot N + \gamma 1 \cdot r - \mu \cdot s - \frac{(1-\rho)\cdot(1-u_1)\cdot\beta\cdot s\cdot(c+u)}{N}$

$$P1 := 16050.0000 + 0.01\, r - 0.0107\, s - 1.980000000 \times 10^{-7}\, s\, (c+u)$$

> $P2 := \frac{(1-\rho)\cdot(1-u_1)\cdot\beta\cdot s\cdot(c+u)}{N} - (\sigma+\mu+0.29796)\cdot c$

$$P2 := 1.980000000 \times 10^{-7}\, s\, (c+u) - 0.47866\, c$$

> $P3 := \delta_1 \cdot c - \left(\varepsilon + q\cdot\alpha_1 + (1-q)\cdot\omega + \mu\right)\cdot p$

$$P3 := 0.1259\, c - 0.292499\, p$$

> $P4 := \delta_3 \cdot c + \varepsilon\cdot p - \left((1-u_2)\cdot\alpha_2 + \omega + \mu\right)\cdot v$

$$P4 := 0.13206\, c + 0.169055\, p - 0.4357\, v$$

> $P5 := \delta_2 \cdot c - (\omega+\mu)\cdot u$

$$P5 := 0.04\, c - 0.0357\, u$$

> $P6 := q\cdot\alpha_1\cdot p + (1-u_2)\cdot\alpha_2\cdot v + \sigma\cdot c - (\mu + \gamma 1)\cdot r$

$$P6 := 0.111744\, p + 0.40\, v + 0.17\, c - 0.0207\, r$$

> *fixpoint* := *solve*({*P1, P2, P3, P4, P5, P6*}, {*s, c, p, v, u, r*})

$$fixpoint := \{c = 0., p = 0., r = 0., s = 1.500000 \times 10^{6}, u = 0., v = 0.\}, \{c = 13634.56854, p = 5868.711273, r = 267514.9244, s = 1.140077259 \times 10^{6}, u = 15276.82749, v = 6409.722527\}$$

> *fix1* := *fixpoint*[1];

$$fix1 := \{c = 0., p = 0., r = 0., s = 1.500000 \times 10^{6}, u = 0., v = 0.\}$$

> *jb* := *Jacobian*([*P1, P2, P3, P4, P5, P6*], [*s, c, p, v, u, r*]);

$$jb := \begin{bmatrix} -0.0107 - 1.980000000\times10^{-7}c - 1.980000000\times10^{-7}u & -1.980000000\times10^{-7}s & 0 & 0 & -1.980000000\times10^{-7}s & 0.01 \\ 1.980000000\times10^{-7}c + 1.980000000\times10^{-7}u & 1.980000000\times10^{-7}s - 0.47866 & 0 & 0 & 1.980000000\times10^{-7}s & 0 \\ 0 & 0.1259 & -0.292499 & 0 & 0 & 0 \\ 0 & 0.13206 & 0.169055 & -0.4357 & 0 & 0 \\ 0 & 0.04 & 0 & 0 & -0.0357 & 0 \\ 0 & 0.17 & 0.111744 & 0.40 & 0 & -0.0207 \end{bmatrix}$$

> *jac1* := *subs*(*fix1*, *evalm*(*jb*)); *eigenvalues*(*jac1*);

$$jac1 := \begin{bmatrix} -0.0107 & -0.2970000000 & 0 & 0 & -0.2970000000 & 0.01 \\ 0. & -0.1816600000 & 0 & 0 & 0.2970000000 & 0 \\ 0 & 0.1259 & -0.292499 & 0 & 0 & 0 \\ 0 & 0.13206 & 0.169055 & -0.4357 & 0 & 0 \\ 0 & 0.04 & 0 & 0 & -0.0357 & 0 \\ 0 & 0.17 & 0.111744 & 0.40 & 0 & -0.0207 \end{bmatrix}$$

$$-0.0107000000000000, -0.0207000000000000, -0.435700000000000, -0.292499000000000, 0.0224919497453628, -0.239851949745363$$

> *fix2* := *fixpoint*[2];

$$fix2 := \{c = 13634.56854, p = 5868.711273, r = 267514.9244, s = 1.140077259 \times 10^{6}, u = 15276.82749, v = 6409.722527\}$$

> *jac2* := *subs*(*fix2*, *evalm*(*jb*)); *eigenvalues*(*jac2*);

$$jac2 := \begin{bmatrix} -0.01642445641 & -0.2257352973 & 0 & 0 & -0.2257352973 & 0.01 \\ 0.005724456414 & -0.2529247027 & 0 & 0 & 0.2257352973 & 0 \\ 0 & 0.1259 & -0.292499 & 0 & 0 & 0 \\ 0 & 0.13206 & 0.169055 & -0.4357 & 0 & 0 \\ 0 & 0.04 & 0 & 0 & -0.0357 & 0 \\ 0 & 0.17 & 0.111744 & 0.40 & 0 & -0.0207 \end{bmatrix}$$

$$-0.280498088858082, -0.296648461526965, -0.0142394395454546 + 0.0113864024868994\,I, -0.0142394395454546 - 0.0113864024868994\,I, -0.0126361209787324, -0.435686608655310$$

> $T1 := \frac{d}{dt}s(t) = \mu \cdot N + \gamma 1 \cdot r(t) - \mu \cdot s(t) - \frac{(1-\rho)\cdot(1-u_1)\cdot\beta\cdot s(t)\cdot(c(t)+u(t))}{N}$

$$T1 := \frac{d}{dt}\, s(t) = 16050.0000 + 0.01\, r(t) - 0.0107\, s(t) - 1.980000000 \times 10^{-7}\, s(t)\, (c(t) + u(t))$$

> $T2 := \frac{d}{dt}c(t) = \frac{(1-\rho)\cdot(1-u_1)\cdot\beta\cdot s(t)\cdot(c(t)+u(t))}{N} - (\sigma + \mu + 0.3669)\cdot c(t)$

$$T2 := \frac{d}{dt}\, c(t) = 1.980000000 \times 10^{-7}\, s(t)\, (c(t) + u(t)) - 0.5476\, c(t)$$

> $T3 := \frac{d}{dt}p(t) = \delta_1 \cdot c(t) - (\varepsilon + q\cdot\alpha_1 + (1-q)\cdot\omega + \mu)\cdot p(t)$

$$T3 := \frac{d}{dt}\, p(t) = 0.1259\, c(t) - 0.292499\, p(t)$$

> $T4 := \frac{d}{dt}v(t) = \delta_3 \cdot c(t) + \varepsilon\cdot p(t) - ((1-u_2)\cdot\alpha_2 + \omega + \mu)\cdot v(t)$

$$T4 := \frac{d}{dt}\, v(t) = 0.13206\, c(t) + 0.169055\, p(t) - 0.4357\, v(t)$$

> $T5 := \frac{d}{dt}u(t) = \delta_2 \cdot c(t) - (\omega + \mu)\cdot u(t)$

$$T5 := \frac{d}{dt}\, u(t) = 0.04\, c(t) - 0.0357\, u(t)$$

> $T6 := \frac{d}{dt}r(t) = q\cdot\alpha_1\cdot p(t) + (1-u_2)\cdot\alpha_2\cdot v(t) + \sigma\cdot c(t) - (\mu + \gamma 1)\cdot r(t)$

$$T6 := \frac{d}{dt}\, r(t) = 0.111744\, p(t) + 0.40\, v(t) + 0.17\, c(t) - 0.0207\, r(t)$$

```
> #DEplot([T1, T2, T3, T4, T5, T6], [s(t), c(t), p(t), v(t), u(t), r(t)], t = 0 .. 300, [[s(0) = 750000, c(0) = 100000, p(0) = 62200, v(0) = 3273, u(0) = 130952, r(0) = 64350]], linecolor = [black], arrows = medium,
    scene = [t, s(t)], stepsize = 0.001);

> #DEplot([T1, T2, T3, T4, T5, T6], [s(t), c(t), p(t), v(t), u(t), r(t)], t = 0 .. 300, [[s(0) = 750000, c(0) = 100000, p(0) = 62200, v(0) = 3273, u(0) = 130952, r(0) = 64350]], linecolor = [black], arrows = medium,
    scene = [t, c(t)], stepsize = 0.001);

> #DEplot([T1, T2, T3, T4, T5, T6], [s(t), c(t), p(t), v(t), u(t), r(t)], t = 0 .. 300, [[s(0) = 750000, c(0) = 100000, p(0) = 62200, v(0) = 3273, u(0) = 130952, r(0) = 64350]], linecolor = [black], arrows = medium,
    scene = [t, p(t)], stepsize = 0.001);

> #DEplot([T1, T2, T3, T4, T5, T6], [s(t), c(t), p(t), v(t), u(t), r(t)], t = 0 .. 300, [[s(0) = 750000, c(0) = 100000, p(0) = 62200, v(0) = 3273, u(0) = 130952, r(0) = 64350]], linecolor = [black], arrows = medium,
    scene = [t, v(t)], stepsize = 0.001);

> #DEplot([T1, T2, T3, T4, T5, T6], [s(t), c(t), p(t), v(t), u(t), r(t)], t = 0 .. 300, [[s(0) = 750000, c(0) = 100000, p(0) = 62200, v(0) = 3273, u(0) = 130952, r(0) = 64350]], linecolor = [black], arrows = medium,
    scene = [t, u(t)], stepsize = 0.001);

> #DEplot([T1, T2, T3, T4, T5, T6], [s(t), c(t), p(t), v(t), u(t), r(t)], t = 0 .. 300, [[s(0) = 750000, c(0) = 100000, p(0) = 62200, v(0) = 3273, u(0) = 130952, r(0) = 64350]], linecolor = [black], arrows = medium,
    scene = [t, r(t)], stepsize = 0.001);
```

LAMPIRAN 3

```
function dx=syam_state1(t, x, u, ti) %ti adalah inputan %t,x,u
adalah variabel
global N alpha1 alpha2 beta gamma sigma epsilon delta delta1
delta2 delta3 miu omega q rho
delta=delta1+delta2+delta3;
x1=x(1);
x2=x(2);
x3=x(3);
x4=x(4);
x5=x(5);
x6=x(6);
u1=u(1,:);
u1=interp1(ti,u1',t);
u2=u(2,:);
u2=interp1(ti,u2',t);
dx=zeros(6,1);

dx(1)=miu.*N+gamma.*x6-miu.*x1-beta.*x1.*(x2+x5).*(1-rho).*(1-
u1)./N;
dx(2)=beta.*x1.*(x2+x5).*(1-rho).*(1-u1)./N-(sigma+miu+delta).*x2;
dx(3)=delta1.*x2-(epsilon+q.*alpha1+(1-q).*omega+miu).*x3;
dx(4)=delta3.*x2+epsilon.*x3-((1-u2).*alpha2+omega+miu).*x4;
dx(5)=delta2.*x2-(omega+miu).*x5;
dx(6)=q.*alpha1.*x3+(1-u2).*alpha2.*x4+sigma.*x2-(miu+gamma).*x6;
end

function dp=dwi_costate1(t, p, x, u, ti)
global a1 a2 a3 a4 N alpha1 alpha2 beta gamma sigma epsilon delta
delta1 delta2 delta3 miu omega q rho
x = interp1(ti,x',t);

x1 = x(1);
x2 = x(2);
x3 = x(3);
x4 = x(4);
x5 = x(5);
x6 = x(6);
u1 = u(1,:);
u2 = u(2,:);

u1 = interp1(ti,u1',t);
u2 = interp1(ti,u2',t);

p1=p(1,:);
p2=p(2,:);
p3=p(3,:);
p4=p(4,:);
p5=p(5,:);
p6=p(6,:);
dp=zeros(6,1);
dp(1)=(p1-p2).*beta.*(x2+x5).*(1-rho).*(1-u1)./N+ miu.*p1;
```

```
dp(2)=-a3+p1.*(1-rho).*(1-u1).*beta.*x1./N-p2.*((1-rho).*(1-
u1).*beta.*x1./N-sigma-miu-delta)-p3.*delta1-p4.*delta3-
p5.*delta2-p6.*sigma;
dp(3)=p3.*(epsilon+q.*(alpha1-omega)+miu+omega)-p4.*epsilon-
p6.*q.*alpha1;
dp(4)=p4.*((1-u2).*alpha2+omega+miu)-p6.*(1-u2).*alpha2;
dp(4)=p4.*(u2+alpha2+(1-u2).*omega+miu)-p6.*(u2+alpha2);
dp(5)=(p1-p2).*beta.*x1.*(1-rho).*(1-u1)./N+p5.*(omega+miu);
dp(6)=-gamma.*p1+(miu+gamma).*p6;
end


function u = dwi_kontrol1(x,p)
global a1 a2 beta alpha2 N rho omega

p1 = p(1,:);
p2 = p(2,:);
p3 = p(3,:);
p4 = p(4,:);
p5 = p(5,:);
p6 = p(6,:);

x1 = x(1,:);
x2 = x(2,:);
x3 = x(3,:);
x4 = x(4,:);
x5 = x(5,:);
x6 = x(6,:);

%fungsi kontrol:
u1=(p2-p1).*(1-rho).*(x2+x5).*beta.*x1./a1;
u2=((p6-p4).*x4.*alpha2)./2.*a2;
u=[u1;u2];
end

function J=dwi_objektif1(x,u,ti)
global a1 a2 a3 a4
x2=x(2,:);
x3=x(3,:);
x4=x(4,:);
x5=x(5,:);
x6=x(6,:);
u1=u(1,:);
u2=u(2,:);

obj=(a1./2).*(u1.^2)+(a2./2).*(u2.^2)+a3.*x2;
J=trapz(ti,obj);


function s=dwi_f_simplebounds(s,Lb,Ub)
% untuk batas bawah
 ns_tmp=s;
 I=ns_tmp<Lb;
 ns_tmp(I)=Lb(I);
```

```
 % untuk batas atas
 J=ns_tmp>Ub;
 ns_tmp(J)=Ub(J);

 % Update u
 s=ns_tmp;


clear all;
clc;
clf;
global a1 a2 a3 a4 N alpha1 alpha2 beta gamma sigma epsilon delta
delta1 delta2 delta3 miu  omega q  rho

% Nilai parameter model
gamma=0.01;
beta = 0.99;
sigma =0.17;
miu=0.0712;
q=0.96;
delta1=0.1259;
delta2=0.04;
delta3=0.13206;
delta=delta1+delta2+delta3;
omega=0.025;
alpha1=0.11624;
alpha2=0.4;
epsilon = 0.169055;
 rho=0.3;

a1=95; a2=5; a3=1;
N=1500000;
% DATA KOTA MAKASSAR
x10=750000;
x20=100000;
x30=62200;
x40=3273;
x50=130952;
x60=64350;

x0=[x10;x20;x30;x40;x50;x60];
%Nilai akhir Costate (syarat transversalitas)
nx=6;
lambdaT=zeros(nx,1);
%Interval waktu
Ntime=10000;
tf=100;
ti=linspace(0,tf,Ntime);
%Batas kontrol
M1=0;
M2=1;
nv=2; %banyaknya kontrol

Lb=M1.*ones(nv,Ntime);
```

```
Ub=M2.*ones(nv,Ntime);
%Parameter Sweep
test=-1;
deltaa=0.001;
k=0;
c=0.5;
%tebakan awal untuk fungsi kontrol u1, u2 dan u3
u=0*ones(nv,Ntime);
%solving sistem tanpa kontrol (u1=0 u2=0 u3=0)
options = odeset('AbsTol',1e-3,'RelTol',1e-3);
xc=ode45(@(t,x) dwi_state1(t, x, u, ti),[0 tf],x0,options);
xc=deval(xc,ti);
%Awal Metode Sweep
x=zeros(nx,Ntime);
p=zeros(nx,Ntime);
while(test<0)
 k=k+1;
 oldx=x;
 oldp=p;
 oldu=u;
 %Forward Runge Kutta
 x=deval(ode45(@(t,x) dwi_state1(t, x, u, ti), [0 tf], x0),ti);
 %Backward Runge Kutta %yg digunakan nilai akhir lambdaT=0
 p=deval(ode45(@(t,p) dwi_costate1(t, p, x, u, ti),[tf
0],lambdaT),ti);
 %menghitung nilai u dari syarat optimal sistem
 u1=dwi_kontrol1(x,p); %menggunakan u dH/du=0
 %membuat u berada dalam interval yang diharapkan
 u1=dwi_f_simplebounds(u1,Lb,Ub);
 %mengupdate nilau u dalam metode sweep menggunakan kombinasi
konveks
% u=0.5*(u1+oldu); %uji Konvergensi u yang pertama
u=u1.*(1-c.^k)+oldu.*c.^k;
% u=0.5*(u1+oldu);
  %menghitung nilai error
 temp1=deltaa*sum(abs(u))-sum(abs(oldu-u));
 temp2=deltaa*sum(abs(x))-sum(abs(oldx-x));
 temp3=deltaa*sum(abs(p))-sum(abs(oldp-p));
 test=min(temp1,min(temp2,temp3)); %Buku Lenhart Hal:55
 %menghitung nilai fungsi tujuan menggunakan u akhir

 J(k)=dwi_objektif1(x,u,ti);
  disp(['it:',num2str(k),',Test:',num2str(test)])
end
figure (1)
%  subplot (221)
 plot(ti,xc(1,:),'r-',ti, x(1,:),'b-','LineWidth',2)
 xlabel('Time (Day) ')
 ylabel('S(t)')
 legend('Without Control', 'With Control')
 axis('tight')
 grid on

 figure (2)
%  subplot (222)
 plot(ti,xc(2,:),'r-',ti, x(2,:),'b-','LineWidth',2)
```

```
 xlabel('Time (Day) ')
 ylabel('C(t)')
 legend('Without Control', 'With Control')
 axis('tight')
 grid on
%  title('Solusi Optimasi Menggunakan Metode Sweep')

 figure (3)
%  subplot (223)
 plot(ti,xc(3,:),'r-',ti, x(3,:),'b-','LineWidth',2)
 xlabel('Time (Day) ')
 ylabel('P(t)')
 legend('Without Control', 'With Control')
%  title('Solusi Optimasi Menggunakan Metode Sweep')
 axis('tight')
 grid on

 figure(4)

%  subplot (221)
 plot(ti,xc(4,:),'r-',ti, x(4,:),'b-','LineWidth',2)
 xlabel('Time (Day) ')
 ylabel('V(t)')
 legend('Without Control', 'With Control')
%  title('Solusi Optimasi Menggunakan Metode Sweep')
 axis('tight')
 grid on

 figure (5)
%  subplot (222)
 plot(ti,xc(5,:),'r-',ti, x(5,:),'b-','LineWidth',2)
 xlabel('Time (Day) ')
 ylabel('U(t)')
 legend('Without Control', 'With Control')
%  title('Solusi Optimasi Menggunakan Metode Sweep')
 axis ('tight')
 grid on

 figure (6)
%  subplot (223)
 plot(ti,xc(6,:),'r-',ti, x(6,:),'b-','LineWidth',2)
 xlabel('Time (Day) ')
 ylabel('R(t)')
 legend('Without Control', 'With Control')
%  title('Solusi Optimasi Menggunakan Metode Sweep')
 axis ('tight')
 grid on

figure (8)
subplot(131)
plot(ti,u(1,:),'r-',ti,u(2,:),'b-','LineWidth',2)
legend('COntrol Function of u_1','Control Function of u_2')
 xlabel('Time (Day) ')
ylabel('Control Function of u_1(t), u_2(t)')
title('Control Function')
```

```
axis('tight')
grid on
subplot(132)
plot(ti,u(1,:),'r-','LineWidth',2)
legend('Control Function of u_1')
 xlabel('Time (Day) ')
ylabel('Control Function of u_1(t)')
title('Control Function')
axis('tight')
grid on
subplot(133)
plot(ti,u(2,:),'b-','LineWidth',2)
legend('Control Function of u_2')
 xlabel('Time (Day) ')
ylabel('Control Function of u_2(t)')
title('Control Function')
axis('tight')
grid on
```