includes asymptomatic infected patients who play a role in the infection cycle without displaying any symptoms, causing a new disease possible. In the new model developed in this section, the notation $P(t)$ indicates the total number of population with seven sub-categories, *i.e.*, susceptible people $S(t)$, vulnerable individuals $V(t)$ who do not show the disease symptoms, clinically symptomatic infected people $I(t)$, asymptomatic infected persons $A(t)$ (with hardly any clinical signs), quarantined people $K(t)$, under treatment individuals $U(t)$, and people who are recuperated $R(t)$. The seafood market $M(t)$ is mainly responsible for this infection because people, who visit the markets and purchase the food, get infected and spread it throughout the environment. As a result, an ordinary differential equations system, which describes the disease, could be derived by applying the above assumptions as below [18]

$$\begin{aligned}
\frac{dS(t)}{dt} &= \beta - \xi S(t) - \upsilon(t)S(t),\\
\frac{dV(t)}{dt} &= -((1-\omega)\sigma_1 + \omega\sigma_2 + \xi + \kappa_v)V(t) + \upsilon(t)S(t),\\
\frac{dI(t)}{dt} &= -(\rho_\iota + \xi + \xi_\iota + \eta_\iota)I(t) + (1-\omega)\sigma_1 V(t),\\
\frac{dA(t)}{dt} &= -(\rho_a + \xi)A(t) + \omega\sigma_2 V(t),\\
\frac{dK(t)}{dt} &= -(\xi + \rho_\kappa + \eta_\kappa)K(t) + \kappa_v V(t),\\
\frac{dU(t)}{dt} &= -(\xi + \rho_u + \xi_u)U(t) + \eta_\iota I(t) + \eta_\kappa K(t),\\
\frac{dR(t)}{dt} &= -\xi R(t) + \rho_\iota I(t) + \rho_a A(t) + \rho_\kappa K(t) + \rho_u U(t),\\
\frac{dM(t)}{dt} &= -\tau_m M(t) + \tau_a A(t) + \tau_\iota I(t),
\end{aligned} \tag{15}$$

in which

$$\upsilon(t) = \frac{\theta_1(I(t) + \phi A(t))}{P(t)} + \theta_2 M(t). \tag{16}$$

The infected people with clinically symptomatic or without clinical symptoms, as well as the infected individuals of seafood markets $(I(t), A(t), M(t))$ can infect the susceptible people to the disease, which is shown as $\upsilon(t)$. For susceptible individuals, the corresponding birth rate is β, and the human mortality rate can be measured by ξ. Healthy people would become infectious after exposure to the infected and asymptomatically infected individuals at the rate θ_1, whereas the transmissibility factor is denoted by ϕ. The number of people who are affected as a result of visiting seafood markets is increased by θ_2. The parameter ω generates the asymptomatic infection. The periods of incubation are represented by σ_1 and σ_2. The parameter κ_v represents the number of individuals who have been exposed to the infection and are being quarantined. The parameters ρ_a and ρ_ι refer to the percentage recuperation of asymptomatic infection and infection, respectively. Also, the parameters ρ_u and ρ_κ are, respectively, the recuperation of hospitalized and quarantined people. The disease-related death rates of hospitalized and infected people are represented by ξ_u and ξ_ι, respectively. In addition, the hospitalization rate for the infected and quarantine individuals has been calculated with η_ι and η_κ, respectively. Not only are the parameters τ_ι and τ_a, respectively, shown the infections came from the infected and asymptomatically infected people at seafood markets, but also the parameter τ_m represents the removed infected individuals from the markets.

3.2. Non-negativity of the solution

Lemma 3.1. *Let $\Delta(t)$ be the state vector of the model (15), i.e.,*

$$\Delta(t) = (S(t), V(t), I(t), A(t), K(t), U(t), R(t), M(t)),$$

and $\Delta(0) = (S_0, V_0, I_0, A_0, K_0, U_0, R_0, M_0) \geqslant 0$ be the non-negative initial state vector. Then the model (15) has a non-negative solution for any time $t > 0$. Moreover, we have $\lim_{t\to\infty} P(t) \leqslant \frac{\beta}{\xi}$ where $P(t)$ would be the total population computed by $P(t) = S(t) + V(t) + I(t) + A(t) + K(t) + U(t) + R(t)$.

Proof. Let us take into account

$$t_{sup} = sup\{t > 0 : \Delta(t) > 0\}.$$

Thus, $t_{sup} > 0$. The first equation of the model (15) leads to the following relation

$$\frac{dS(t)}{dt} = \beta - \xi S(t) - \upsilon(t)S(t) = \beta - S(t)(\xi + \upsilon(t)), \tag{17}$$

where $\upsilon(t) = \frac{\theta_1(I(t)+\phi A(t))}{P(t)} + \theta_2 M(t)$. Thus, the Eq. (17) can be written as

$$\begin{aligned}
&\frac{d}{dt}\left\{S(t)\exp\left(\xi t + \int_0^{t_{sup}} \upsilon(s)ds\right)\right\}\\
&\quad = \beta\exp\left(\xi t + \int_0^{t_{sup}} \upsilon(s)ds\right).
\end{aligned} \tag{18}$$

Therefore,

$$\begin{aligned}
&S(t_{sup})\exp\left(\xi t_{sup} + \int_0^{t_{sup}} \upsilon(s)ds\right) - S(0)\\
&\quad = \int_0^{t_{sup}} \beta\exp\left(\xi y + \int_0^{y} \upsilon(\zeta)d\zeta\right)dy,
\end{aligned} \tag{19}$$

such that

$$\begin{aligned}
S(t_{sup}) = {} & S(0)\exp\left\{-\left(\xi t_{sup} + \int_0^{t_{sup}} \upsilon(s)ds\right)\right\}\\
& + \exp\left\{-\left(\xi t_{sup} + \int_0^{t_{sup}} \upsilon(s)ds\right)\right\}\\
& \times \int_0^{t_{sup}} \beta\exp\left(\xi y + \int_0^{y} \upsilon(\zeta)d\zeta\right)dy > 0.
\end{aligned} \tag{20}$$

We can follow a similar strategy for the remaining equations in the system (15) to prove $\Delta(t) > 0$ for all $t > 0$. For further assertion, consider that the initial conditions satisfy $0 < S_0, V_0, I_0, A_0, K_0, U_0, R_0 \leqslant P(t)$. In the system (15), all the equations except the last one are added together; thus, we obtain

$$\frac{dP(t)}{dt} = \beta - \xi P(t) - \xi_\iota I(t) - \xi_u U(t) \leqslant \beta - \xi P(t).$$

Consequently, we have

$$\lim_{t\to\infty} P(t) \leqslant \frac{\beta}{\xi}.$$

□