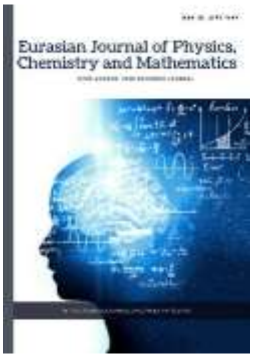

# On Some Types Nano – M – Continuous Functions

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ABSTRACT

The aim of this work is to definition new type of Nano- M -continuous function. It is named Nano-M-(Nano semi, Nano pre_ , Nanoα_ , Nanoβ_ Nanoδ − Nano θ_ , Nanoθ_, Nano Re_, Nano$\theta_S$_) continuous function and to reach a relationship with types of Nano- M - cont function are studied with some examples, properties and necessary theorems are studied on it.

**Keywords:** Nano-Continuous function , Nano – M – Continuous function

## 1. Introduction

In 2013 Thivagar M. Lellis [10] idea of Nano-topological space ($N\_TS$)with respect to a subset $X$ of universe $U$ which is defined as an upper and lower approximation of $x$. The element of $N\_TS$ is called a Nano-open sets($N$_os).

In 1963 levine [2] establish the notion of semi-cont. function. In 1983 M.E. Abd EL-Monsef [1] establish the notion of $\beta$-cont. function, $\alpha$-cont function [12], pre-cont. function [9], $\delta$- cont. function, $\theta -$ semi cont. function, Regular-cont. function [3], $\theta -$ cont. function. In 2022 [4] Mohmmed N.H and Shihab A. A and we will intrudes new type of Nano-cont. function and introduced definition of Nano-M - open set.

## 2. Preliminaries

A subset A of a space (X, T) is called semi-open(se_o) [10]( resp.α-open(α _o) [10], β-open(β_o) [7], pre open(pr_o) [10], δ − open(δ_o) [6], θ-open(θ_o) [8], Regular-open(Re_o) [10], θ-semi-open( $\theta_S$_o)[6] set. The complement of se_o (resp., α_o, β_o, pr_o,δ_o, θ_o, Re_o, $\theta_S$_o) set is said to be semi-closed(se_c) (resp.,$\alpha$-c, $\beta$-c, pre-c, $\delta$-c, $\theta$-c, Regular-c, $\theta_S$_c) set. Intersection of all se_ c (resp. $\alpha$- c, $\beta$- c, pre - c, $\delta$- c, $\theta$- c, Regular- c, $\theta_S$_c) sets continuing $A$ is called the semi- closure (resp. $\alpha$- closure, $\beta$- closure, pre -closure, $\delta$- closed, $\theta$- closure, Regular- closure, $\theta$- semi - closure) and is dented by $Scl(A)$[ resp. $\alpha cl(A), \beta cl(A), pcl(A), \theta cl(A), Rcl(A)$ , $\delta cl_\theta(A)$].

The union of all se_o. (resp. $\alpha$_o., $\beta$_o., pr_o., $\delta$_o., $\theta$_o., Re_o., $\theta_S$_o.) sets contained in $A$ is said semi- interior (resp. $\alpha$- interior, $\beta$- interior, pre interior, $\delta$- interior, $\theta$- interior, Regular- interior, $\theta$- semi - interior) and denoted by $Sint(A)$[resp.$\alpha int(A), \beta int(A), pint(A), \theta int(A), Rint(A)$ , $\delta int_\theta(A)$] .

The family of all semi-cont (resp.,$\alpha$-cont, $\beta$-cont, pre-cont, $\delta$-cont, $\theta$-cont, Regular-cont, $\theta$-semi-cont) is denoted by $\delta cont(x), [resp., \alpha - cont(x), \beta - cont(x), \theta - cont(x), R - cont(x), \delta - cont(x)]$.

**Definitions 2.1.:[10]** Let $(U, T_R(x))$ be a $N\_TS$ and $A \subseteq U$. Then $A$ be called.

1- $N_\alpha$-o. if $A \subseteq Nint(Ncl(N_{int}(A)))$.
2- N-pre-o. if $A \subseteq Nint(Ncl(A))$.
3- $N_\delta$-o. if $A \subseteq Ncl(Nint(A))$.
4- $N_{\theta S}$-o. if $A \subseteq \overline{A^0_\theta}$. [6]
5- $N_R$-o. if $A = Nint(Ncl(A))$.
6- $N_\theta$-o. if $A = NA^0_\theta$. [8]
7- $N_\delta$-o. if $A \subseteq \overline{A^0_\delta}$. [6]
8- $N_\beta$-o. if $A \subseteq Ncl(Nint(Ncl(A)))$. [7]

**3. Some Types of M-N-continuity**

**Definition 3.1:[4]** let $(U, T_R(x))$ be $N\_TS$. The subset $A$ of $U$ is called MN-open set (MN – o.s.) in $N\_TS$ if $A \subseteq \overline{NA^0_\theta} \cup \overline{NA_\delta}^0$.

**Remark 3.2**: The complement of MN – o.s. is said to be MN -closed set(MN – c.s.)

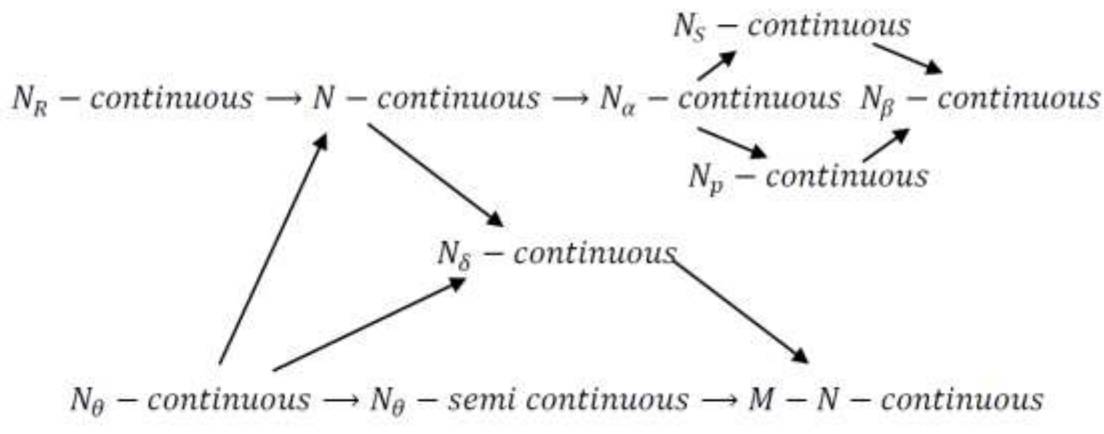
**Definitions 3.3:** Let $(U, T_R(x))$ and $(Q, T_R(H))$ be $N\_T$ spaces. Afunction $f: (U, T_R(x)) \rightarrow (Q, T_R(A))$ is called:

1- Nano-continuous($N - Con$) if $f^{-1}(A)$ is $N$-openset in U , ∀ N-open set $A$ in $Q$. [11]
2- Nano$\alpha$ −continuous ($N_\alpha - Con$) if $f^{-1}(A)$ is $N_\alpha$-open set in $U$, ∀ $N$-open set A in $Q$. [12]
3- N $pre$ - continuous($N - pre - Con$) if $f^{-1}(A)$ is N-pre-o.s. in $U$, ∀ $A$ $is$ N − pre − o.s. in $Q$. [9]
4- $N_\beta$-continuous($N_\beta - Con$) if $f^{-1}(A)$ is $N_\beta - o.s.$ in $U$,∀ $A$ is $N_\beta - o.s.$ in $Q$. [5]
5- $N_S$-continuous($N_\delta - Con$) if $f^{-1}(A)$ is $N_S - o.s.$ in $U$, ∀ $AN_S - o.s.$ is in $Q$. [13]
6- $N_R$-continuous ($N_R$ - $Con$ ) if $f^{-1}(A)$ is $N_R - o.s.$ in $U$, ∀ $A$ is $N_R - o.s.$ in $Q$. [3]
7- $N_\theta$-continuous($N_\theta - Con$) if $f^{-1}(A)$ is $N_\theta - o.s.$ in $U$, ∀ $A$ is $N_\theta - o.s.$ in Q.
8- $N_\theta$-semi-continuous($N_{\theta S} - Con$) if $f^{-1}(A)$ is $N_{\theta S} - o.s.$ in $U$, ∀ $A$is $N_{\theta S} - o.s.$ in $Q$.
9- $N_\delta$-continuous($N_\delta - Con$) if $f^{-1}(A)$ is $N_\delta - o.s.$ in $U$, ∀ $A$ is $N$-open set in $Q$.

**Definition 3.4:** let $(U, T_R(x))$ and $(Q, T_R(\text{H}))$ be M-Nano-topological space ($MN - TS$). Then a function f: $(\text{U}, T_R(x)) \rightarrow (Q, T_R(\text{H}))$ is $M_N$-continuous ($M_N - Con$) on $U$ if $f^{-1}(A)$ is MN – o.s. in $U$, ∀$A$ is MN – o.s. in $Q$.

**Remark 3.5:** The following diagram explains the relations between continuous functions

**Diagram (1)**




**The relationship between continuous functions**

**Example 3.6:** Let $U = \{a, b, c, \text{d}\}$ with $T_R(x) = \{U, \phi, \{a, b, c\}\}$, then MN – o.s.$(U)$ ={ $U$, ∅,{a},{b},{c},{a,b},{a,c},{b,c},{a,b,c}}and let $Q = \{1,2,3,4\}$ with $T_R(\text{H}) = \{Q, \phi, \{1,2,3\}\}$ ,then MN – o.s.$(Q)$ ={ $Q$, ∅,{1},{2},{3},{1,2},{1,3},{2,3},{1,2,3}}.Define $f: U \rightarrow Q$ $as$ $f(a) = 1, f(b) = 2$ and $f(c) = 3$. Therefore $f$ is $M_N$-cont. mapping on $U$ , so the above diagram (1) achieves it.

**Theorem 3.7:** A function $f:(U,T_R(x)\rightarrow(Q,T_R(H))$ is $M_N-Con \Leftrightarrow f^{-1}(A)$ MN – c.s. in $Q$ is MN – c.s. in $U$.

**Proof:** h is $M_N-Con$, $H$ is MN – c.s. in $Q$. That is, $Q-H$ is MN – o.s. in $Q$ Since $h$ is $M_N-Con$, $f^{-1}(Q-\text{H})$ is MN – o.s. in $U$. That is, $U-f^{-1}(H)$ is MN – o.s. in $U$. Therefore, $f^{-1}(\text{H})$ is MN – c.s. in $U$. Thus, the inverse image of every MN – c.s. be MN – c.s. Let G be MN – o.s. in $Q$, Then $Q-G$ is MN – cs in $Q$. Then $f^{-1}(\text{H}-G)$ is $M_N$-closed in $U$. That is, $U-f^{-1}$ is $M_N$-closed in $U$. Therefore $f^{-1}(G)$ is MN – o.s. in $U$. Thus, the inverse image of every MN – o.s. in $Q$ is MN – o.s. in $U$. That is, $h$ is $M_N-Con$ on $U$.

**Theorem 38:** A function $f:(U,T_R(\text{x})\rightarrow(Q,T_R(y))$ is $M_N-Con \Leftrightarrow M_Ncl(f^{-1}(A))\subseteq f^{-1}(M_Ncl(A))$, $\forall A\subseteq Q$.

**Theorem 3.9:** A function $f:(U,T_R(\text{x}))\rightarrow(Q,T_R(y))$ is $M_N-Con \Leftrightarrow f^{-1}(M_N\,int(A))\subseteq M_N\,int(f^{-1}(A)),\forall A\subseteq Q$.

**Proof:** let $f$ be $M_N-Con$ and $A\subseteq Q$. Then $M_N\,int(A)$ is MN – o.s. in $(Q,T_R(y))$. Therefore $f^{-1}(M_N\,int(A))$ is MN – o.s. in $(U,T_R(\text{x}))$. That is $f^{-1}(M_N\text{ int }(A))=$ $M_N\,int[f^{-1}(M_N\text{ int(A)})]$. Also, $M_N\text{ int}(A)\subseteq A\Rightarrow f^{-1}(M_N\text{ int}(A))\subseteq f^{-1}(A)$. Therefore, $M_N\,int(f^{-1}(M_N\text{ int}(A))\subseteq M_N\,int(f^{-1}(A))$. That is $f^{-1}(M_N\text{ int }(A))\subseteq M_N\text{int}(f^{-1}(A))$. Conversely, let $f^{-1}(M_N\text{int}(A))\subseteq M_N int(f^{-1}(A)),\forall A\subseteq Q$. If $A$ is $M_N$-open in $Q$, $M_N\text{int}(A)=A$. Also $f^{-1}(M_N\text{ int}(A))\subseteq M_N int(f^{-1}(A))$. That is $f^{-1}(A)\subseteq M_N\text{ int}(f^{-1}(A)))$. But $M_N int(f^{-1}(A))\subseteq f^{-1}(A)$. Therefore $f^{-1}(A)=M_N\text{int}(f^{-1}(A))$. Thus, $f^{-1}(A)$ is MN – o.s. in $U,\forall$MN – o.s.$A$ in $Q$. Therefore, $f$ is $M_N-Con$.

**Definitions 3.10:** Let $(U,T_R(x))$ and $(Q,T_R(H)$ be $MN-TS$ with respect to $X$ and $H$ respectively. A function $f:(U,T_R(x))\rightarrow(Q,T_R(\text{H})$ be called:

1- $M_{N\alpha}$-cont if $f^{-1}(A)$ is $M_{N\alpha}$-o.s in $U,\forall M_N$-o.s. $A\subseteq Q$.
2- $M_{Ns}$-cont if $f^{-1}(A)$ is $M_{Ns}$-o.s. in $U,\forall M_N$-o.s. $A\subseteq Q$.
3- $M_{Np}$-cont if $f^{-1}(A)$ is $M_{Np}$-o.s in $U,\forall M_N$-o.s. $A\subseteq Q$.
4- $M_{N\delta}$-cont if $f^{-1}(A)$ is $M_{N\delta}$-o.s. in $U,\forall M_N$-o.s. $A\subseteq Q$.
5- $M_{N\beta}$-cont if $f^{-1}(A)$ is $M_{N\beta}$-o.s .in $U,\forall M_N$-o.s. $A\subseteq Q$.
6- $M_{N\theta}$-cont if $f^{-1}(A)$ is $M_{N\theta}$-o.s. in $U,\forall M_N$-o.s. $A\subseteq Q$.
7- $M_{N\theta s}$-cont if $f^{-1}(A)$ is $M_{N\theta s}$-o.s. in $U,\forall M_N$-o.s. $A\subseteq Q$.

**Example 3.11:** $U=\{1,2,3\}$ with $U/R=\{\{1\},\{2,3\}\}$ and $X=\{2,3\}$. Then $T_R(x)=\{U,\phi,\{2,3\}\}$, $M_N$ −closed sets are $U,\phi$ and $\{1\}$, ${T_R}^{\alpha}(x)=\{U,\phi,\{2,3\}\}$ and let $Q=\{a,b,c\}$ with $Q/R=\{\{a\},\{b,c\}\}$ and $H=\{b,c\}$. Then $T_R(H)=\{Q,\phi,\{b,c\}\}$. Define $f:U\rightarrow Q$ as $f(1)=a,f(2)=b$ and $f(3)=\text{c},f^{-1}(\{b,c\})=\{2,3\}\in T_R^{\alpha}(x)$ and inverse image of $\emptyset$ and $Q$ are $\phi$ and $U$ respectively. Therefore, $f$ is $M_{N\alpha}$-cont function.

**Example 3.12:** $U=\{1,2,3\}$ with $\text{U/R}=\{\{1\},\{2,3\}\}$, $X=\{1,2\}$. Then $T_R(x)=\{U,\phi,\{1\},\{2,3\}$, $M_{Nso}(U,x)=\{U,\phi,\{1\},\{2,3\}\}$. Suppose $Q=\{a,b,c\}$ with $Q/R=\{\{a,b\},\{c\}\}$ and $H=\{b,c\}$. Then $T_R(H)=\{Q,\phi,\{c\},\{a,b\}\}$. Define $f:U\rightarrow Q$ as $f(1)=\text{c},f(2)=b,f(3)=a$, then $f^{-1}(\{c\})=\{1\}$ and $f^{-1}(\{a,b\})=\{2,3\}$. Hence, $f$ is $M_{Ns}-\text{con}$.

**Example 3.13 :** $U=\{1,2,3\}$ with $\text{U/R}=\{\{1\},\{2,3\}\}$, $X=\{2,3\}$. Then $T_R(x)=\{U,\phi,\{1\},\{2,3\}$, MN – cs are $U,\emptyset$ and $\{1\}$. $M_{Npo}(U,x)=\{U,\phi,\{2\},\{3\},\{1,2\},\{1,3\},\{2,3\}\}$ and let $Q=\{a,b,c\}$ with $Q/R=\{\{a\},\{b,c\}\}$ and $H=\{b,c\}$. Then $T_R(H)=\{Q,\phi,\{b,c\}\}$. Define $f:U\rightarrow Q$ as $f(1)=a,f(2)=b,f(3)=c$, then $f^{-1}(\{\text{b},\text{c}\})=\{2,3\}\in M_{Npo}(U,x)$, and $f^{-1}(\{\emptyset,\text{Q}\})=\emptyset$ and $U$ respectively. That $f$ is $M_{Np}$-con.

**Example 3.14 :** $U=\{1,2,3\}$ with $\text{U/R}=\{\{1\},\{2,3\}\}$, $X=\{1,3\}$. Then $T_R(x)=\{U,\phi,\{1\},\{2,3\}$, $M_{Nc-}$o.s. and $U,\emptyset,\{1\}$ and $\{2,3\}$. The $M_{NR}$-o.s. in $U$ are $M_{NR}(U,x)=\{U,\phi,\{1\},\{2,3\}\}$ and let $Q=\{p,q,s\}$ with $Q/R=\{\{p\},\{q,s\}\}$ and $H=\{\text{q},\text{s}\}$. Then $T_R(H)=\{Q,\phi,\{q,s\}\}$. Define $f:U\rightarrow Q$ as $f(1)=p,f(2)=q,f(3)=s$, then $f^{-1}(\{q,s\})=\{2,3\}\in M_{NR}(U,x)$, and $f^{-1}(\{p\})=1\in M_{NR}(U,x)$. Since $f^{-1}(\{\emptyset,Q\})=\emptyset$ and $U$ respectively. Therefore $f$ is $M_{NR}$-cont function.

**Example 3.15:** $U=\{a,b,c,d\}$ with $\text{U/R}=\{\{a,b\},\{c,d\}\}$, $X=\{a,b\}$. Then $T_R(x)=$

$\{U, \phi, \{a, b\}\}$, MN – c.s. in $U$ are $U, \emptyset$ and $\{c, d\}$. $M_{N\beta o}(U, x) = \{U, \phi, \{a\}, \{b\}, \{a, b\}, \{a, c\}. \{a, d\}, \{a, b, c\}, \{b, c, d\}, \{c, d, a\}, \{a, d, b\}\}$ and let $Q = \{r, p, q, s\}$ with $Q/R = \{\{r, p\}, \{q, s\}\}$ and $H = \{r, p\}$. Then $T_R(H) = \{Q, \phi, \{r, p\}\}$. MN – c.s. in $Q$ are $Q, \emptyset$ and $\{q, s\}$. Define $f: U \to Q$ as $f(a) = r, f(b) = p, f(c) = q, f(d) = s$. Then $f^{-1}(\{Q, \emptyset\})$ are $U$ and $Q$. And $f^{-1}(\{r, p\}) = \{a, b\} \in M_{N\beta o}(U, x)$. Hence, $f$ is $M_{N\beta}$-cont.

**Definitions 3.16:[11]** A function $f: (U, T_R(x)) \to (Q, T_R(H))$ is called:

1- MN- open map if the image of every MN – o.s. in $U$ is MN – o.s. in $Q$.
2- MN- closed map if the image of every MN – c.s. in $U$ is MN – c.s. in $Q$.

**Theorem 3.17 :** A function $f: (U, T_R(x)) \to (Q, T_R(H))$ is MN – closed map $\Leftrightarrow M_N cl(f(A)) \subseteq f(M_N cl(A)), \forall A \subseteq U$.

Proof: Let $f$ MN- closed, $f(M_N cl(A))$ is MN-closed in $Q$( because $M_N cl(A)$ is MN – c.s. in $Q$). Since $A \subseteq M_N cl(A)$ then $f(A) \subseteq f(M_N cl(A))$. Therefore $M_N cl(f(A)) \subseteq f(M_N cl(A))$ if $f(M_N cl(A)$ is MN – c.s. containing $f(A)$.

Conversely, if $M_N cl(f(A)) \subseteq f(M_N cl(A)), \forall A \subseteq U$ and if $E$ is MN – c.s. in $U$, then $M_N cl(E)= E$ ,then $f(E) \subseteq f(M_N cl(E))= f(E)$.Thus , $f(E) \subseteq M_N cl(f(E))$ is MN – c.s. in $Q$. Then $f$ is a MN-closed map.

**Theorem 3.18 :** A function $f: (U, T_R(x)) \to (Q, T_R(H))$ is MN – open map $\Leftrightarrow f(M_N int(A)) \subseteq M_N int(f(A)), \forall A \subseteq U$.

Proof is to the of similar to the theorem 3.18.

**Definition 3.19 :** A function $f: (U, T_R(x)) \to (Q, T_R(H))$ be called a $M_N$-homomorphism ($Hom_{M_N}$)if:

1) $f$ is $1 - 1$ and onto.
2) $f$ is $M_N$-continuous.
3) $f$ is $M_N$-open function.

**Theorem 3.20**: Let $f: (U, T_R(x)) \to (Q, T_R(H))$ be a bijective mapping . Then $f$ is $Hom_{M_N}$ iff $f$ is MN- closed and $M_N$-continuous.

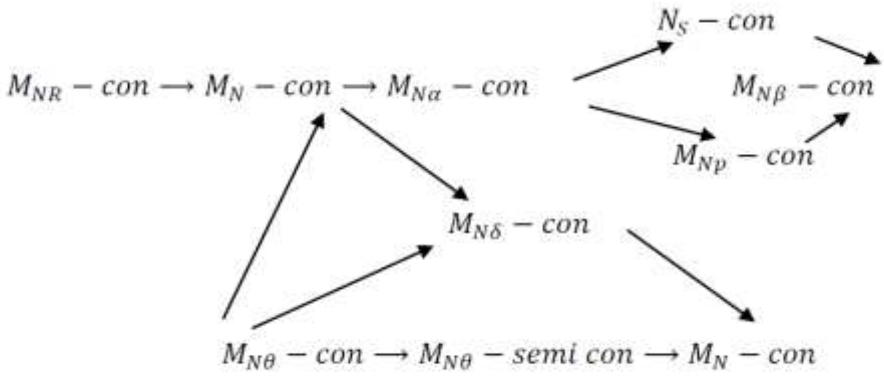
Proof. Suppose that $f$ be a $Hom_{M_N}$, then $f$ is $M_N$-continuous. For any G is MN – c.s. in $U$, we get $U/$G is MN – o.s. and $f(U/$G ) is MN – o.s. in $Q$. That is, $Q/f$(G) is MN – o.s. in $Q$. When $f$(G) is MN – c.s. in $Q$(because the image of ∀ MN – c.s. in $U$ is MN – c.s. in $Q$)then $f$ is MN- closed. Conversely, since $f$ is MN- closed and $M_N$-continuous and K is MN – o.s.in $U$, then $U/$K is MN – c.s. in $U$. Since $f$ is MN – c.s. and $f(U/$K )= $Q - f$(K) is MN- closed in $Q$. Therefore, $f$(K) is MN- open in $Q$. Then $f$ is $Hom_{M_N}$.

**Theorem 3.21**: Let $f: (U, T_R(x)) \to (Q, T_R(H))$ be a one-one map, then $f$ is a $Hom_{M_N}$ iff $M_N cl(f(A)) = f(M_N cl(A)), \forall A \subseteq U$.

**Result 3.22 :** 1) $M_{NR}$-continuous $\Longrightarrow M_N$-continuous.
2) $M_N$-continuous $\Longrightarrow M_{N\alpha}$-continuous.
3) $M_{N\alpha}$-continuous $\Longrightarrow M_{NS}$-continuous.
4) $M_{N\alpha}$-continuous $\Longrightarrow M_{Np}$-continuous.
5) $M_{NS}$-continuous and $M_{Np}$-continuous $\Longrightarrow M_{N\beta}$-continuous.
6) $M_N$-continuous $\Longrightarrow M_{N\delta}$-continuous $\Longrightarrow M_N$-continuous.
7) $M_{N\theta}$-continuous $\Longrightarrow M_{N\delta}$-continuous and $M_{N\theta}$-semi-continuous and $M_N$-continuous. 8) $M_{N\theta}$-continuous $\Longrightarrow M_N$-continuous.

**Remark 3.23:** the following diagram explains the relations between $M_N$-continuous functions.

**Diagram (2)**

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