

# Simulazione Next-Event Per Sistema Di Ride-Hailing e Ride-Sharing

Progetto PMCNS

*Greta Luna Ancora 0369455*

*Gaia Meola 0369454*

*Nicola Violante 0362469*

# Agenda

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## ► Introduzione

- ▶ Panoramica dello studio
- ▶ Oggetto di studio
- ▶ Obiettivo dell'analisi

## ► Modello Base

- ▶ Modello concettuale, modello delle specifiche, modello computazionale
- ▶ Design degli esperimenti
- ▶ Verifica e validazione

## ► Modello Migliorativo

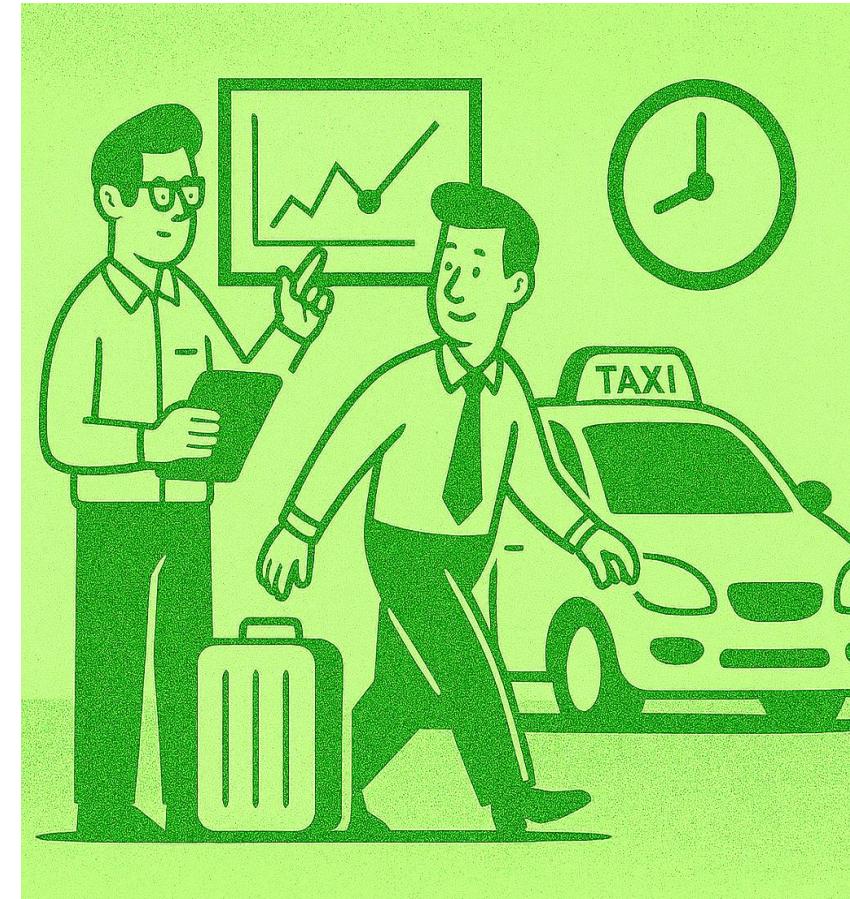
- ▶ Modello concettuale, modello delle specifiche, modello computazionale
- ▶ Design degli esperimenti
- ▶ Verifica e validazione

## ► Conclusioni



# Panoramica dello studio

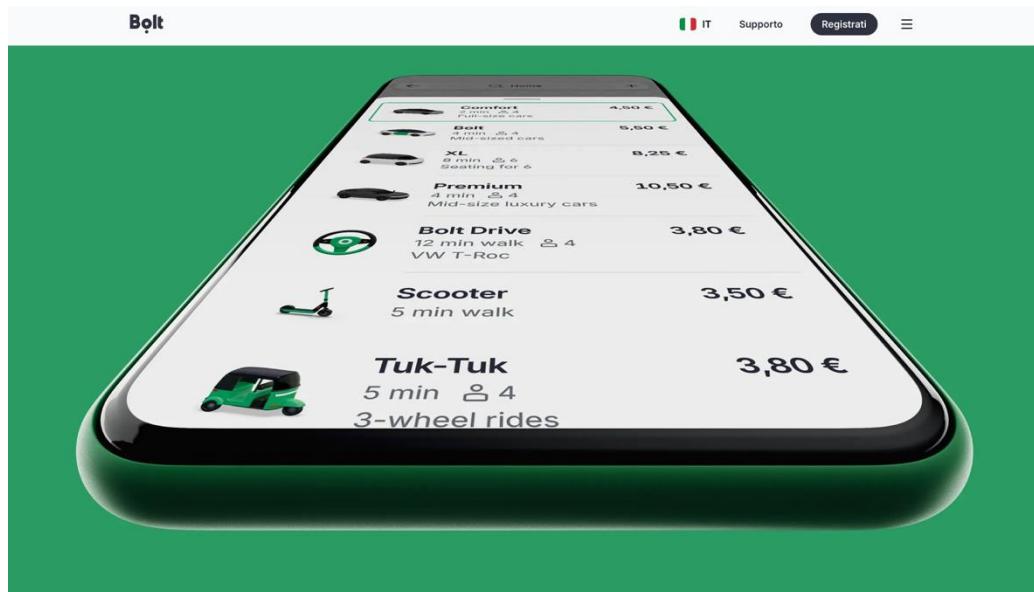
- ▶ Prima parte – Fascia operativa a cario medio-alto
  - ▶ Ipotesi: **allocazione dinamica delle risorse**
  - ▶ Studio limitato ad **una sola fascia di carico medio-alto**
- ▶ Seconda parte – Fasi di minor e maggior affluenza
  - ▶ Simulazione su **un'intera giornata lavorativa** (24 ore)
  - ▶ Tasso di arrivo **variabile ( $\lambda$ )** in base alla fascia oraria
  - ▶ Analisi delle **configurazioni ottimali** per ciascun livello di carico



# PRIMA PARTE

# Introduzione

- **Bolt** è un'azienda estone attiva nel settore della mobilità urbana che, tra i vari servizi offerti, include il **ride-hailing** tramite una piattaforma digitale.

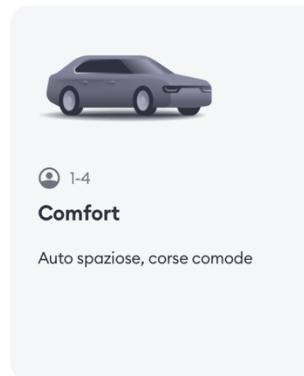


“For decades, cities have been built for **cars**, not people... We’re partnering with cities to help people make the switch towards light vehicles and shared mobility options... to transform urban areas back into sustainable, people-friendly spaces.”

*Markus Villig, Founder & CEO*

# Oggetto di studio

Spostati velocemente e a prezzi accessibili con Bolt.



I prezzi indicati rappresentano una stima e possono variare in base alle condizioni del traffico, a ritardi imprevisti, sconti e altri fattori.

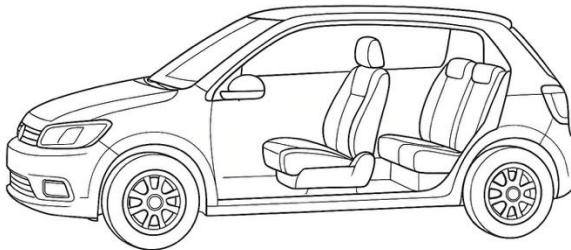
## ► Astrazioni

- Un **intervallo temporale** fisso
- Un **numero di veicoli**, sia complessivamente sia per ciascuna tipologia, fisso per tutto l'intervallo temporale
- L'assenza di una **modellazione spaziale** esplicita
- Una **domanda delle richieste di corsa stabile** per tutto l'intervallo temporale

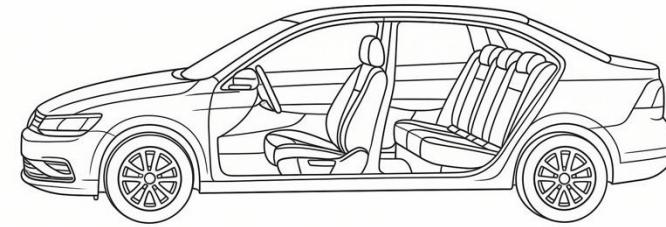
# Oggetto di studio

## ► Astrazioni

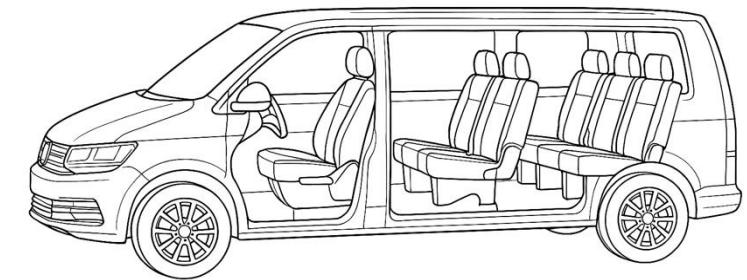
- Tre centri di servizio, ciascuno dedicato alla gestione delle richieste per una specifica tipologia:



**SMALL**



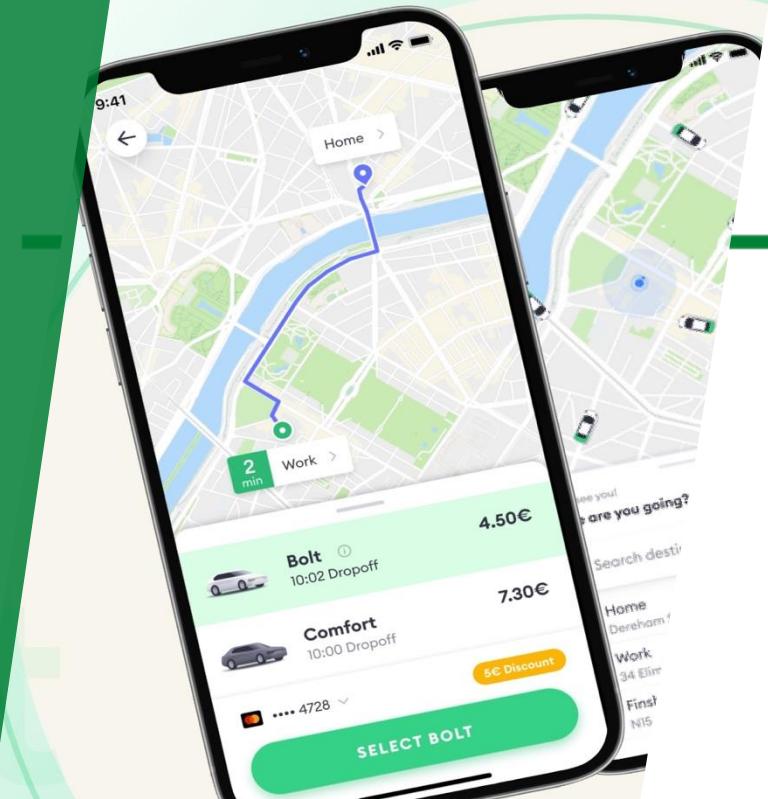
**MEDIUM**



**LARGE**

- Algoritmo di matching semplificato tramite una politica di tipo **selection in order**

# Obiettivo dell'analisi



Gestione dello **stesso** carico di lavoro con l'introduzione del servizio di **ride-sharing**

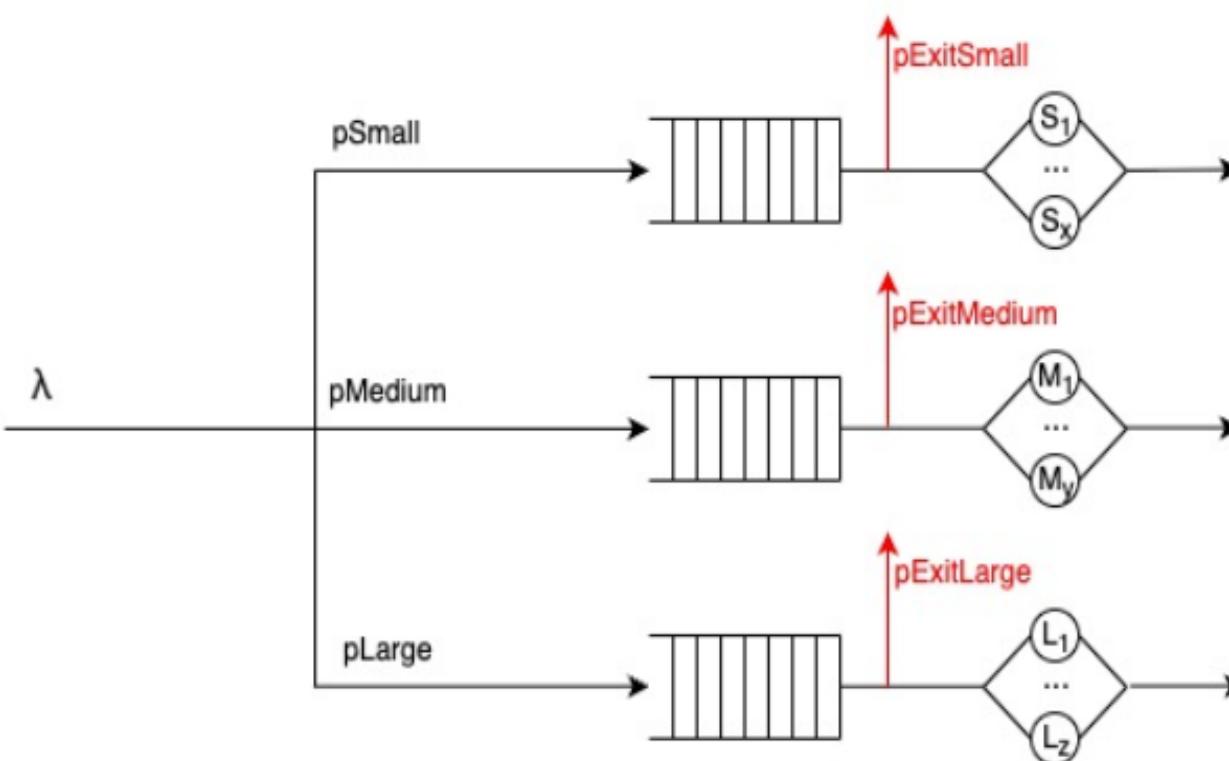
## RIDE SHARING



**Riduzione** del numero totale di veicoli impiegati grazie all'introduzione del servizio di **ride-sharing**

# MODELLO BASE

# Modello concettuale



- ▶ **Stato del sistema:**

$$(n_{small}, n_{medium}, n_{large})$$

- ▶ **Eventi del sistema:**

- ▶ **L'arrivo** di una richiesta di corsa per una specifica tipologia di veicolo
- ▶ Il **termine** di una corsa che rende nuovamente un veicolo disponibile
- ▶ **L'annullamento** di una richiesta di corsa

# Modello delle specifiche

## ► Calcolo del lambda:

$$\lambda_{Small} = \frac{\rho}{\frac{E(S_{Server})}{N_{Small}}} \implies \lambda = \frac{\rho \cdot N_{Small}}{E(S_{Server}) \cdot (1 - p_{ExitSmall}) \cdot p_{Small}}$$

$$\lambda_{Small} = (1 - p_{ExitSmall}) \cdot p_{Small} \cdot \lambda$$

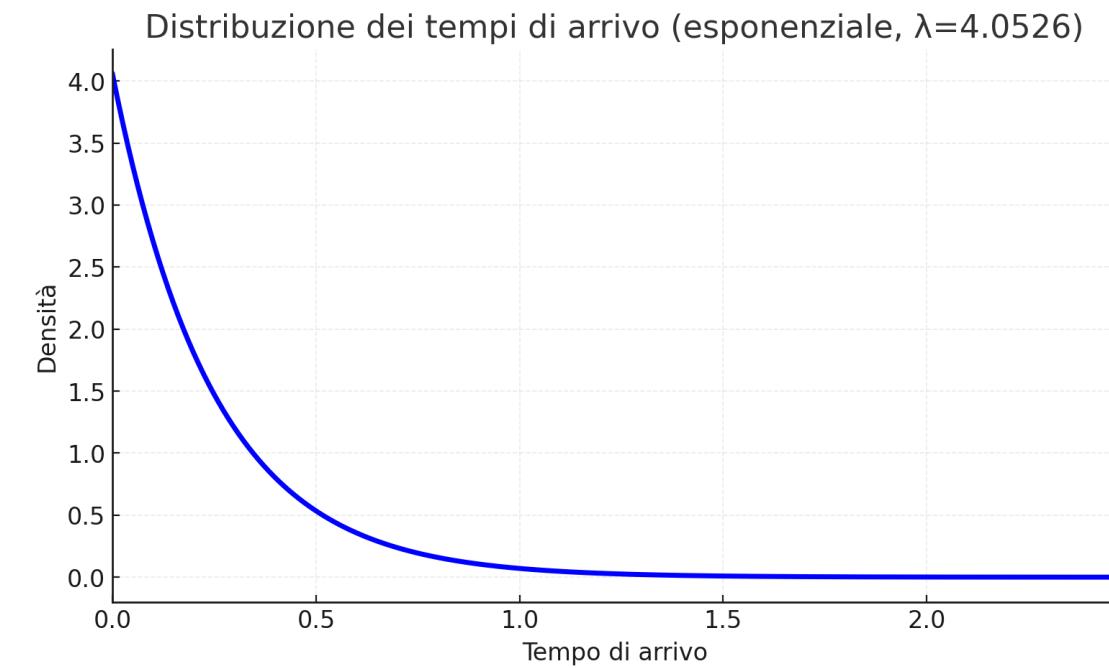
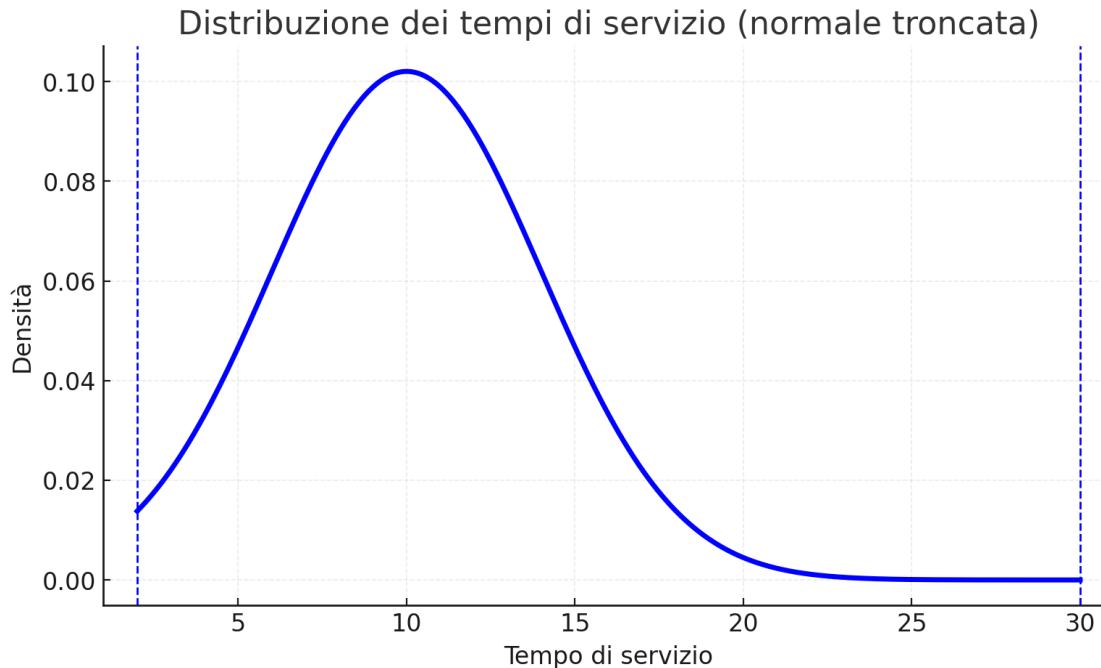
## ► Matrice di routing ed equazioni di traffico:

	Esterno	Centro Small	Centro Medium	Centro Large
Esterno	0	$p_{Small}$	$p_{Medium}$	$p_{Large}$
Centro Small	1	0	0	0
Centro Medium	1	0	0	0
Centro Large	1	0	0	0

$$\begin{cases} \lambda_{Small} = p_{Small}(1 - p_{ExitSmall})\lambda \\ \lambda_{Medium} = p_{Medium}(1 - p_{ExitMedium})\lambda \\ \lambda_{Large} = p_{Large}(1 - p_{ExitLarge})\lambda \end{cases}$$

# Distribuzioni

- ▶ Tempi di servizio: **Gaussiana (10, 4)** troncata tra [2,30]
- ▶ Tempi di arrivo: **Esponenziale ( $4.05263161$ )**



# Modello computazionale

- ▶ Linguaggio di programmazione: **Java**
- ▶ Linguaggio di programmazione per la generazione dei grafici: **Python**
- ▶ Libreria per la generazione dei grafici: **matplotlib**
- ▶ Suddivisione in 6 packages:
  - ▶ *Centers*
  - ▶ *Configuration*
  - ▶ *Controller*
  - ▶ *Libs*
  - ▶ *Model*
  - ▶ *Utils*



- ▶ Link repository Github: <https://github.com/NicolaViolante/BoltSimulator.git>

# Pseudo-Random Number Generator

- ▶ Libreria per la generazione di numeri casuali: **rngs** (compatibile con rng)
- ▶ Fino a **256 stream** indipendenti di numeri casuali, di cui solo uno è attivo alla volta e selezionato tramite **SelectStream**
- ▶ I numeri vengono generati con la funzione **Random**
- ▶ Tutti gli stream vengono inizializzati una sola volta con **PlantSeeds**
- ▶ All'inizio di ogni replica, lo stato viene recuperato con **GetSeed**

# Stream

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Lo **stream 1** è dedicato alla funzione ***getNextArrivalTimeSimpleCenter()***

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Lo **stream 2** è dedicato alla funzione ***getNextArrivalTimeRideSharing()***

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Lo **stream 3** è dedicato alla funzione ***getServiceTimeSimple()***

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Lo **stream 4** è dedicato alla funzione ***getServiceTimeRideSharing()***

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Lo **stream 5** gestisce la probabilità di uscita dal servizio tradizionale (***P\_EXIT***)

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Lo **stream 6** gestisce la probabilità di uscita dal servizio ride-sharing (***P\_EXIT***)

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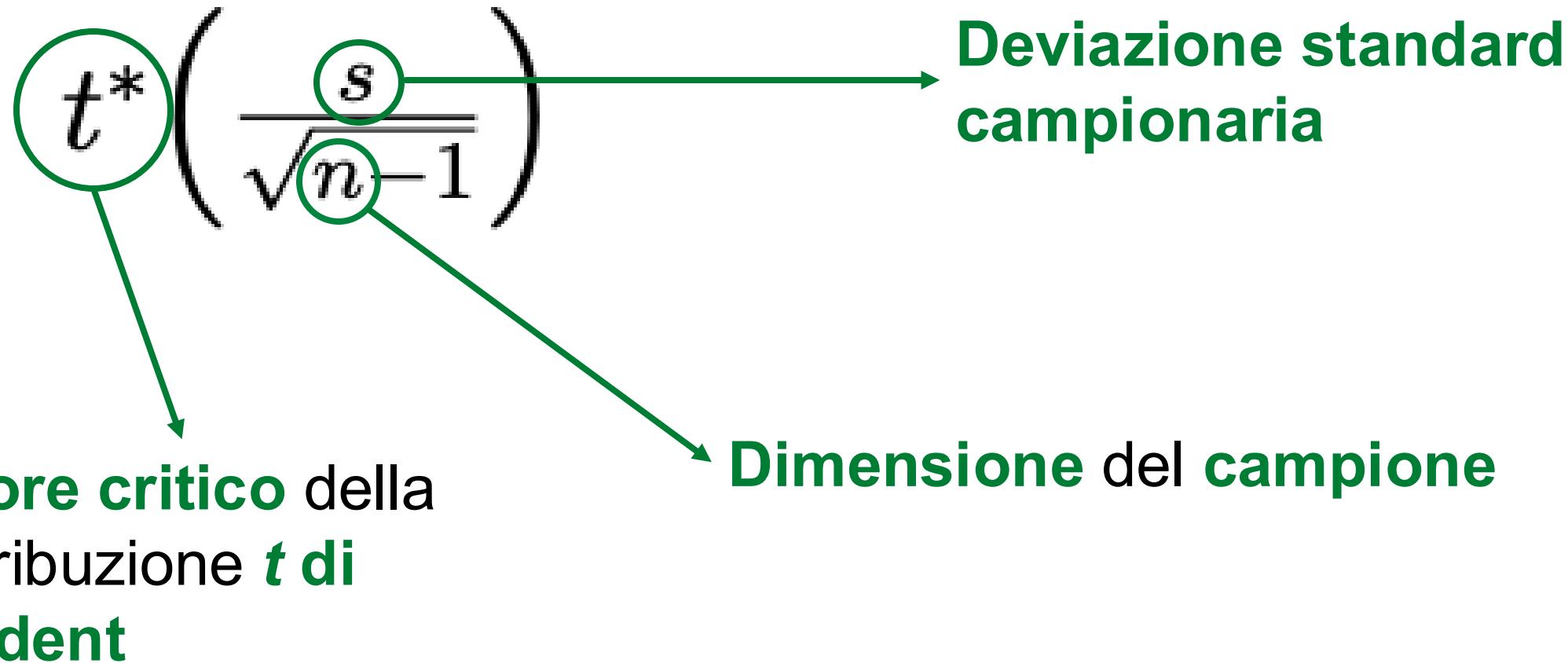
Lo **stream 7** gestisce la probabilità di match con risorsa occupata (***P\_MATCH\_BUSY***)

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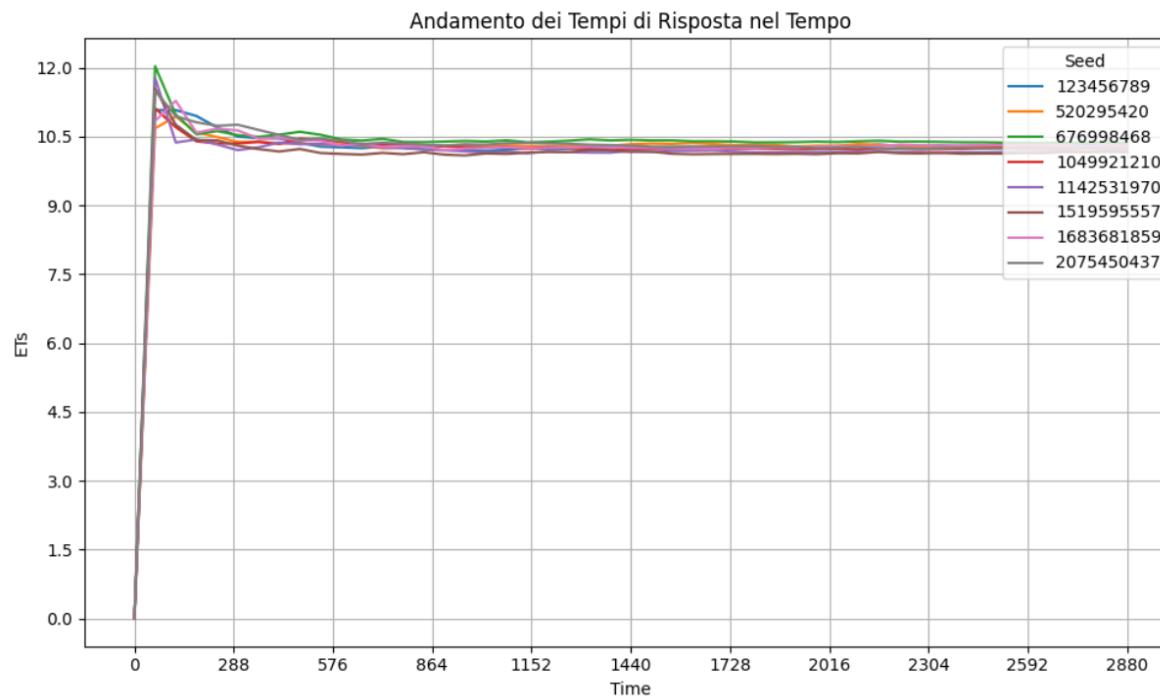
Lo **stream 8** è dedicato alla funzione ***getNumeroPosti()***

# Design degli esperimenti

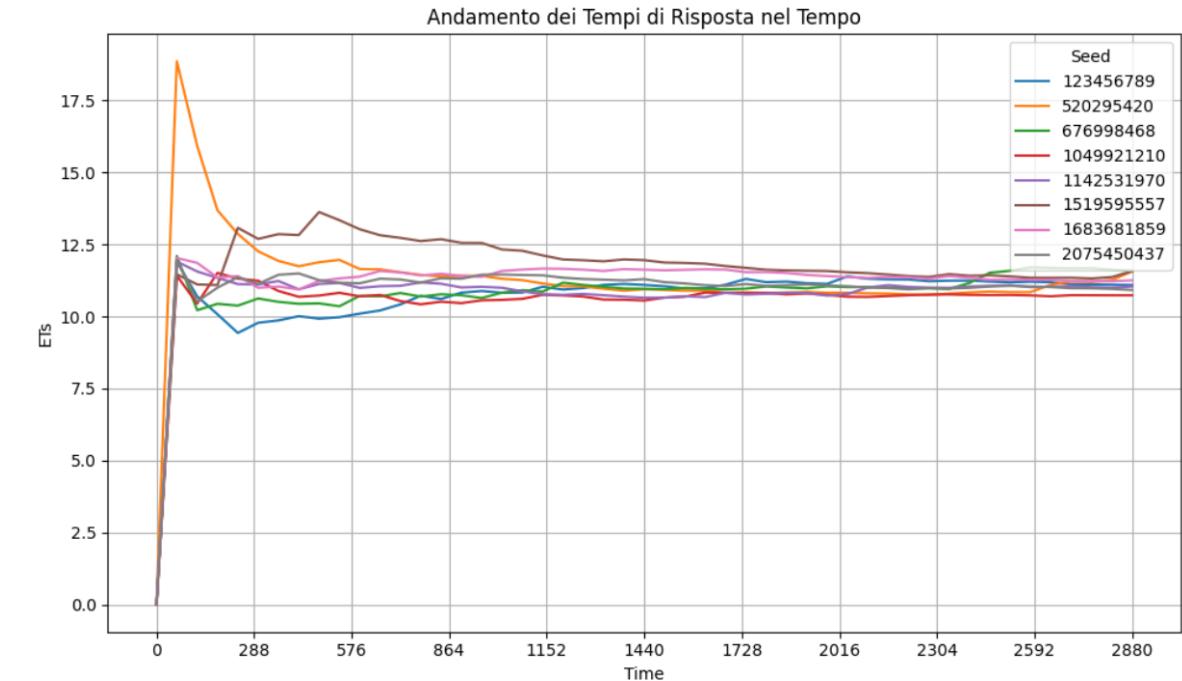
## ► Intervalli di confidenza:



# Analisi del transitorio

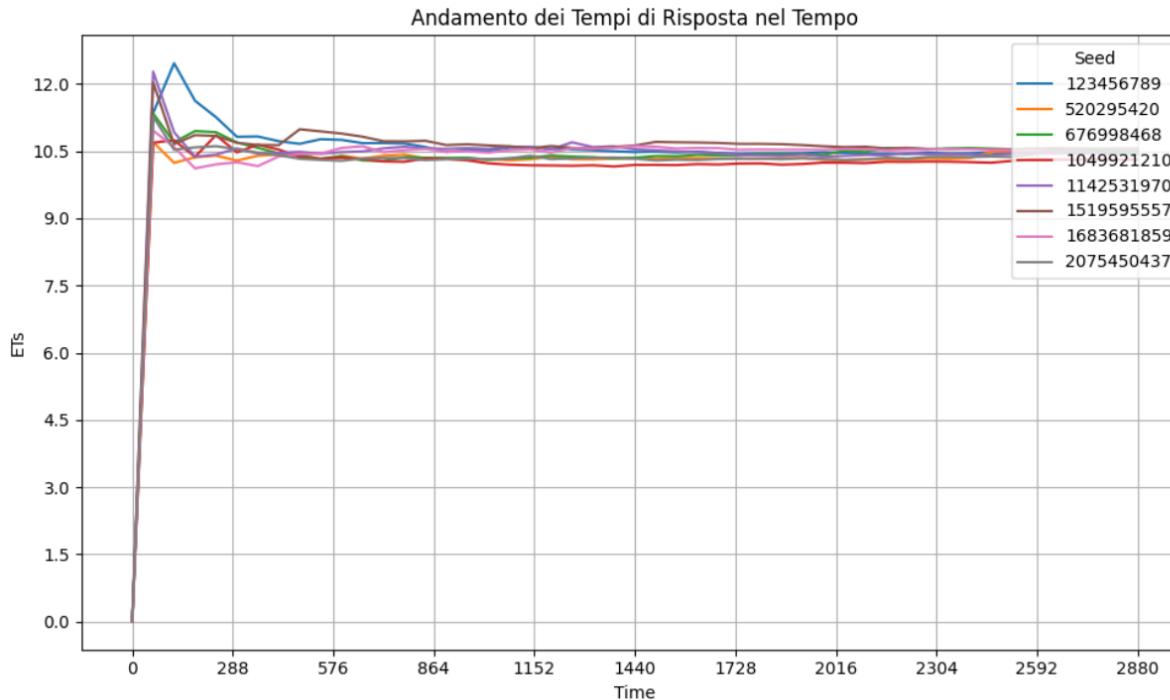


CENTRO SMALL

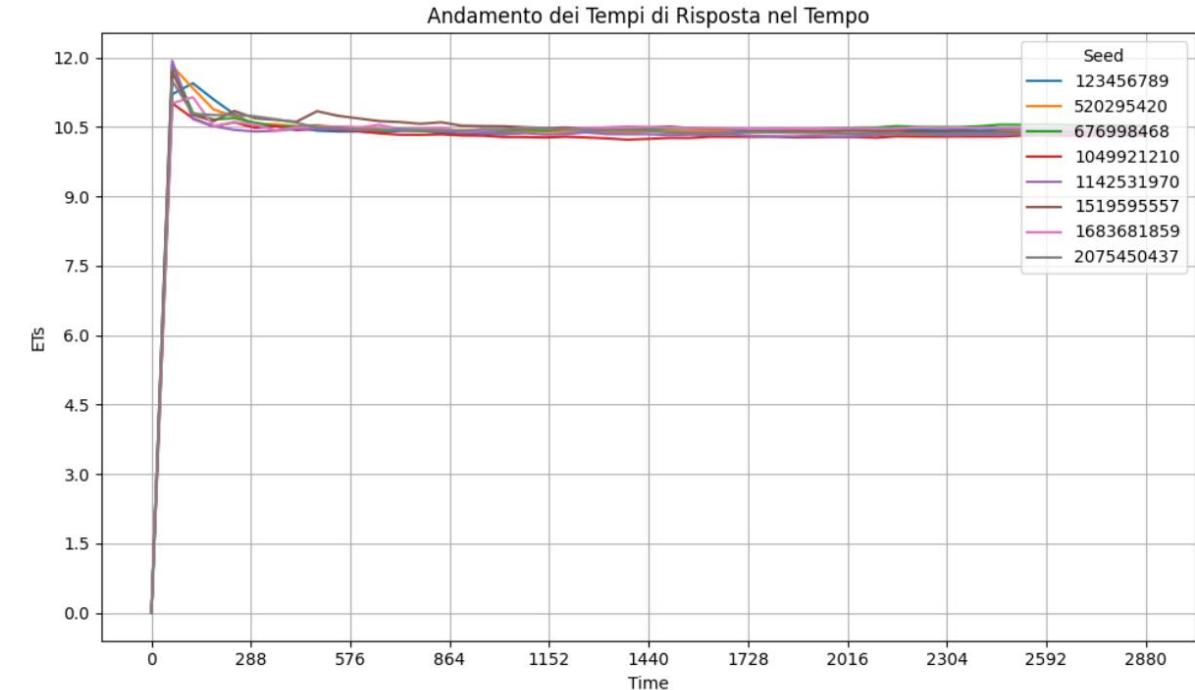


CENTRO MEDIUM

# Analisi del transitorio



CENTRO LARGE



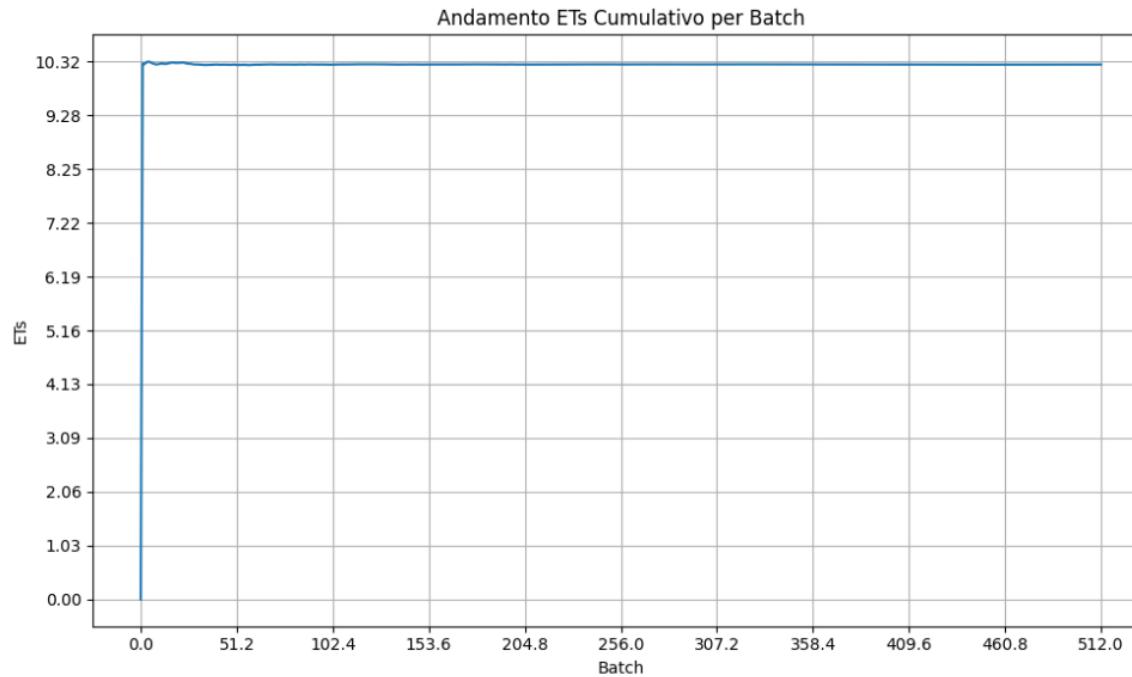
SISTEMA

# Simulazione a orizzonte infinito

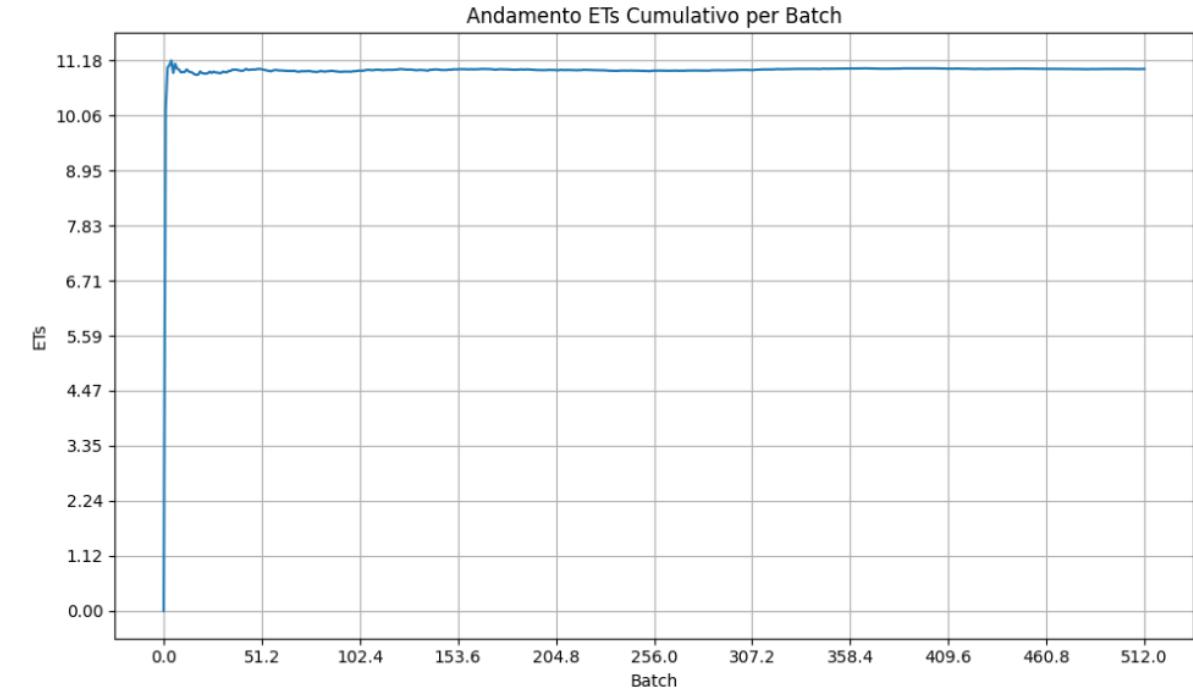
- ▶ Principali motivazioni dello studio a **orizzonte infinito**:
  - ▶ Bolt è un'applicazione già consolidata e ampiamente utilizzata
  - ▶ Singola fascia operativa che parte da uno stato iniziale vuoto
- ▶ Metodo delle **batch means** ( $b, k$ ):
  - ▶ I parametri scelti sono  **$b = 2048$**  e  **$k = 512$**
- ▶ **Lag-1 autocorrelazione** tra le medie di batch **inferiore a 0.2**

# Simulazione a orizzonte infinito

- ▶ b: **2048**
- ▶ k: **512**



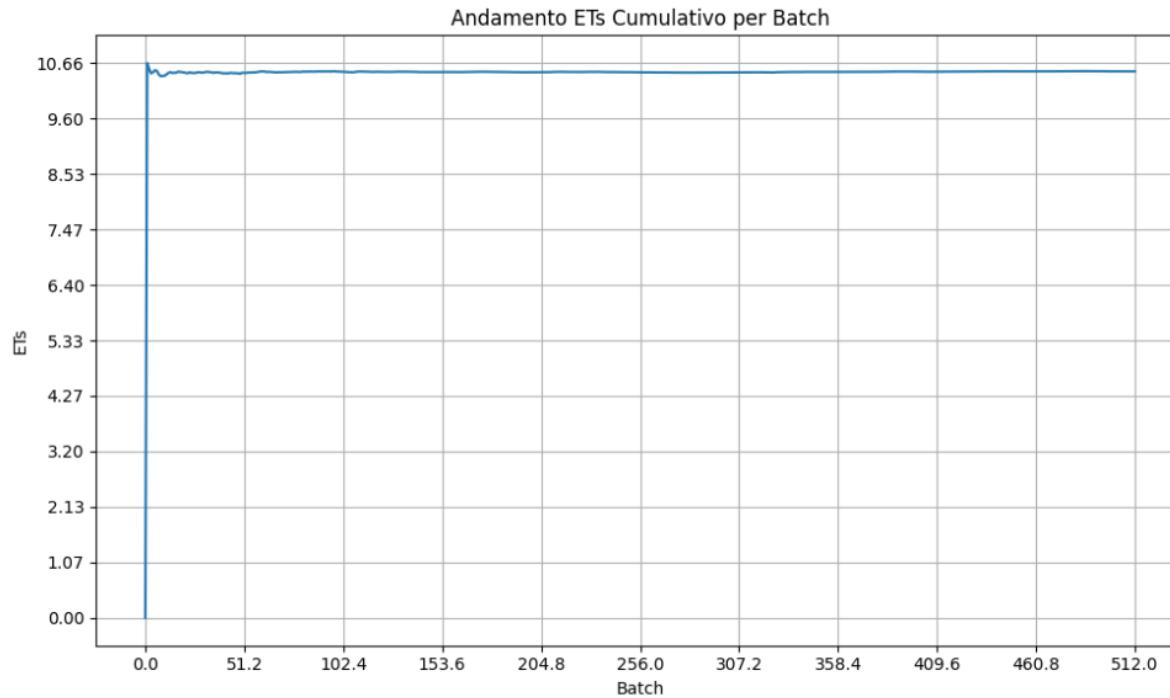
**CENTRO SMALL**



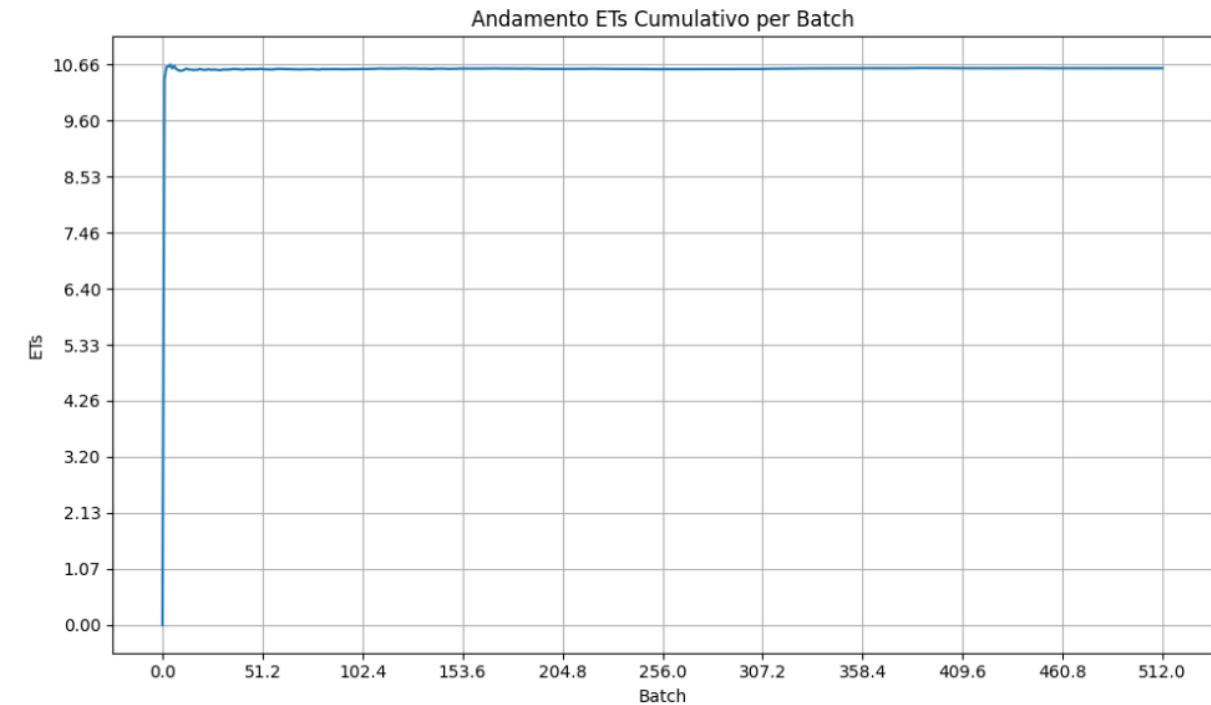
**CENTRO MEDIUM**

# Simulazione a orizzonte infinito

- ▶ b: **2048**
- ▶ k: **512**



CENTRO LARGE



SISTEMA

# Verifica e Validazione

## ► Verifica

- Confronto con simulazioni analitiche, impostando tempi di servizio **esponenziali**

- **Centro small:**

Indice	Valore analitico	Valore empirico	Intervallo di confidenza
$E[N_S]$	23.1826	23.2178	$\pm 0.0763$
$E[T_S]$	10.0358	10.0549	$\pm 0.0249$
$E[N_Q]$	0.0826	0.0849	$\pm 0.0100$
$E[T_Q]$	0.0358	0.0364	$\pm 0.0042$
$\rho$	0.7	0.7010	$\pm 0.0022$

- **Centro medium:**

Indice	Valore analitico	Valore empirico	Intervallo di confidenza
$E[N_S]$	4.2967	4.2611	$\pm 0.0582$
$E[T_S]$	11.1603	11.0491	$\pm 0.1183$
$E[N_Q]$	0.4467	0.4318	$\pm 0.0331$
$E[T_Q]$	1.1603	1.0977	$\pm 0.0801$
$\rho$	0.6417	0.6383	$\pm 0.0051$

- **Centro large:**

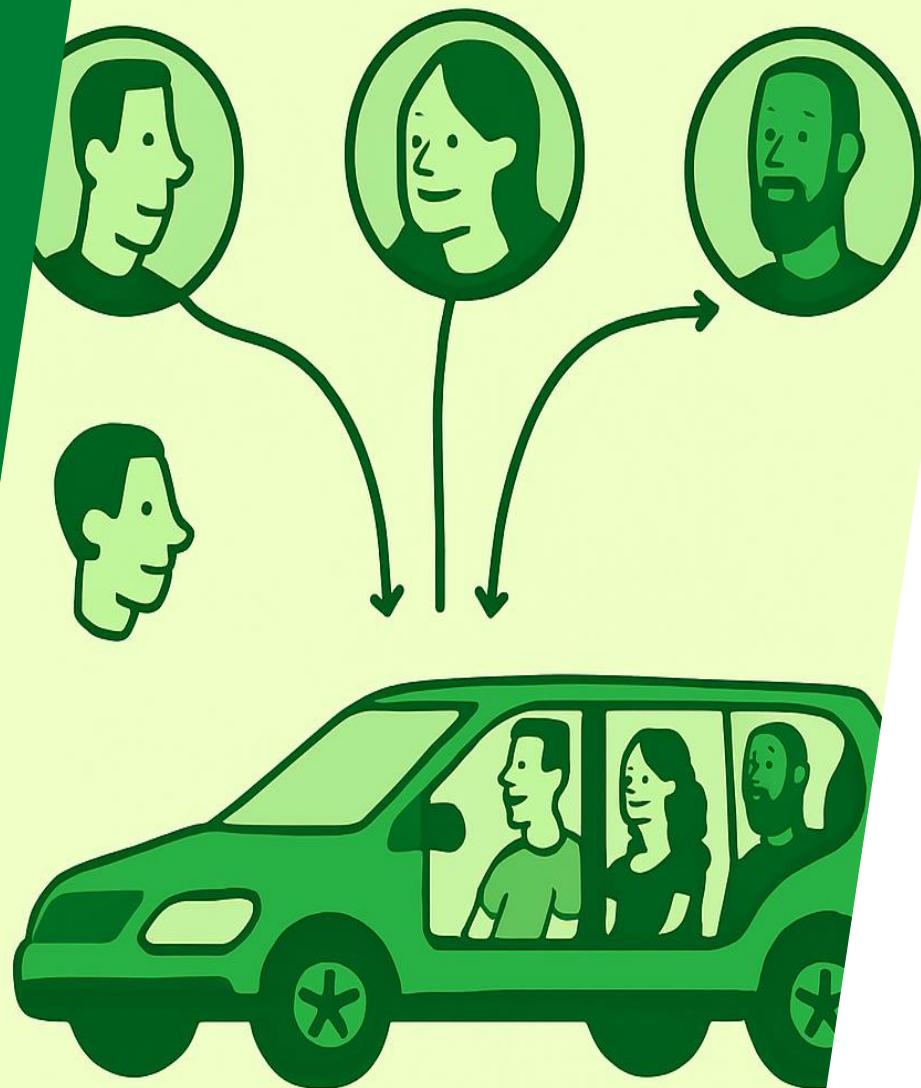
Indice	Valore analitico	Valore empirico	Intervallo di confidenza
$E[N_S]$	11.9640	11.9875	$\pm 0.0720$
$E[T_S]$	10.3585	10.3514	$\pm 0.0488$
$E[N_Q]$	0.4140	0.4186	$\pm 0.0312$
$E[T_Q]$	0.3585	0.3583	$\pm 0.0260$
$\rho$	0.7218	0.7212	$\pm 0.0031$

## ► Validazione

- **Non** possibile per mancanza di dati empirici e misurazioni del sistema reale



# MODELLO MIGLIORATIVO



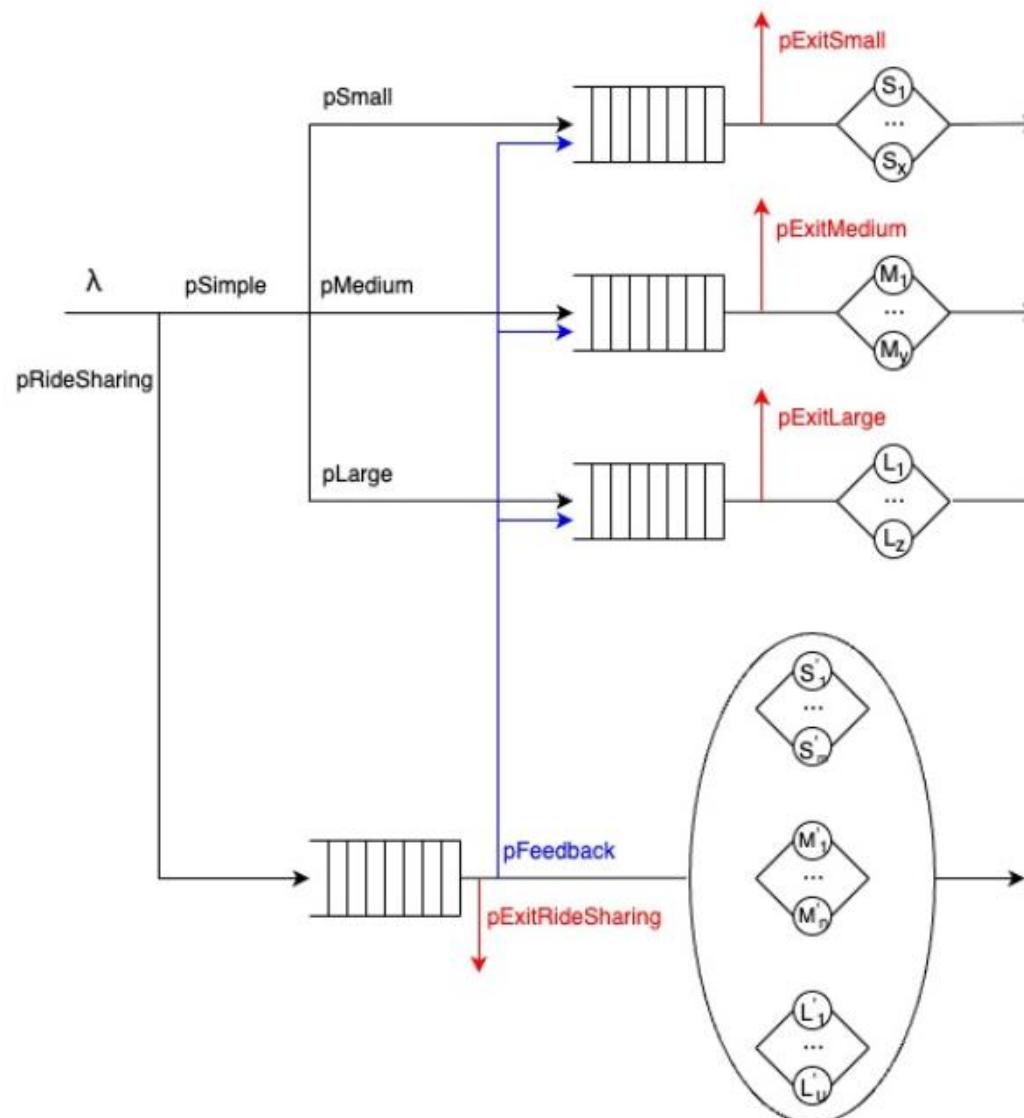
## Introduzione del servizio di ride-sharing

### ► Astrazioni

- Incremento del tempo di servizio **proporzionale** al numero di richieste servite
- Algoritmo di matching **semplificato** in cui viene verificato il numero di posti **disponibili**, mentre la compatibilità dei percorsi viene astratta attraverso una **probabilità di matching**



# Modello concettuale



## ► Stato del sistema:

$$(n_{small}, n_{medium}, n_{large}, n_{ride}, s_1, \dots, s_m, L_{richieste})$$

## ► Eventi del sistema:

- **L'arrivo** di una richiesta di corsa per una specifica tipologia di veicolo
- Il **termine** di una corsa che rende nuovamente un veicolo disponibile
- L'**annullamento** di una richiesta di corsa
- L'**arrivo** di una richiesta di corsa per il servizio ride-sharing
- Il **matching** tra una richiesta e un veicolo con posti disponibili per il servizio di ride-sharing
- Il **termine** di una corsa che prevede l'utilizzo del servizio di ride-sharing

# Modello delle specifiche

## ► Calcolo del lambda:

$$\lambda = \frac{\rho \cdot N_{Small}}{E(S_{Server}) \cdot (1 - p_{ExitSmall}) \cdot p_{Small}}$$

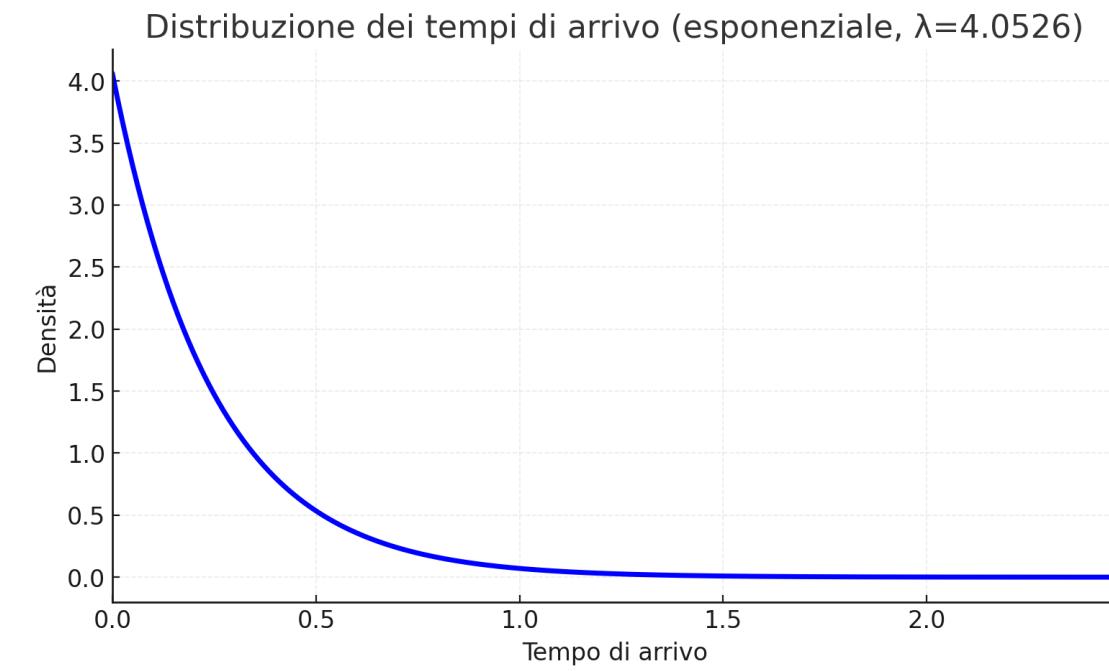
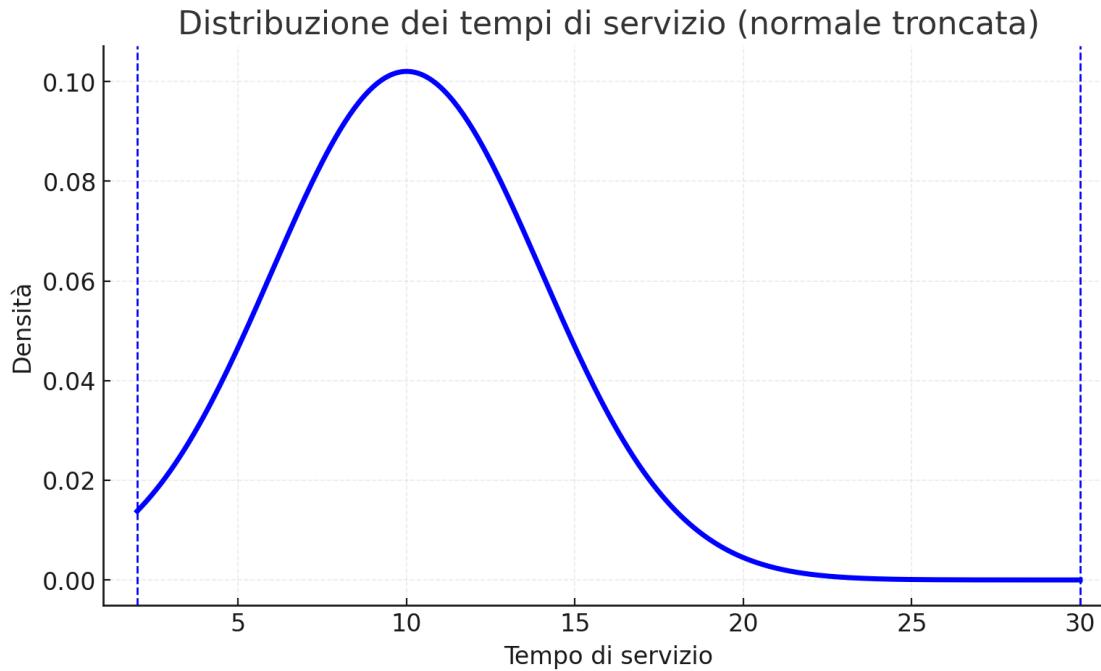
## ► Matrice di routing ed equazioni di traffico:

	Esterno	Centro small	Centro medium	Centro large	Centro ride-sharing
Esterno	0	$p_{Simple} p_{Small}$	$p_{Simple} p_{Medium}$	$p_{Simple} p_{Large}$	$p_{RideSharing}$
Centro small	1	0	0	0	0
Centro medium	1	0	0	0	0
Centro large	1	0	0	0	0
Centro ride-sharing	$1 - p_{Feedback}$	$p_{Feedback} p_{Small}$	$p_{Feedback} p_{Medium}$	$p_{Feedback} p_{Large}$	0

$$\left\{ \begin{array}{l} \lambda_{Small} = p_{Small} p_{Simple} (1 - p_{ExitSmall}) \lambda + p_{RideSharing} p_{Feedback} (1 - p_{ExitSmall}) p_{Small} \lambda \\ \lambda_{Medium} = p_{Medium} p_{Simple} (1 - p_{ExitMedium}) \lambda + p_{RideSharing} p_{Feedback} (1 - p_{ExitMedium}) p_{Medium} \lambda \\ \lambda_{Large} = p_{Large} p_{Simple} (1 - p_{ExitLarge}) \lambda + p_{RideSharing} p_{Feedback} (1 - p_{ExitLarge}) p_{Large} \lambda \\ \lambda_{RideSharing} = p_{RideSharing} (1 - p_{ExitRideSharing}) (1 - p_{Feedback}) \lambda \end{array} \right.$$

# Distribuzioni

- Tempi di servizio: **Gaussiana (10, 4)** troncata tra [2,30]
- Tempi di arrivo: **Esponenziale ( $4.05263161$ )**



# Modello computazionale

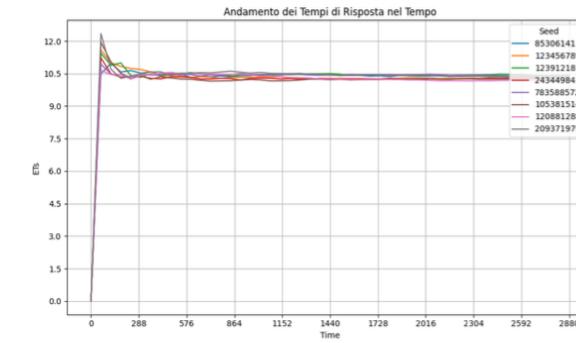
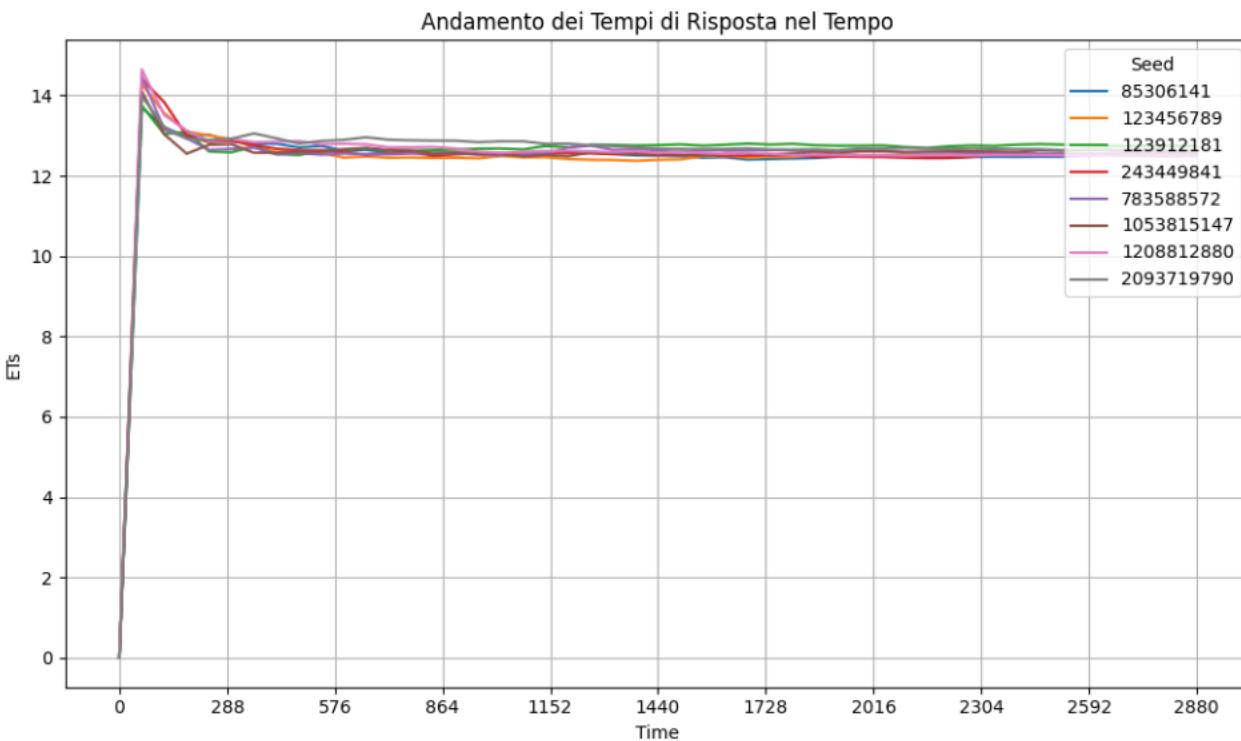
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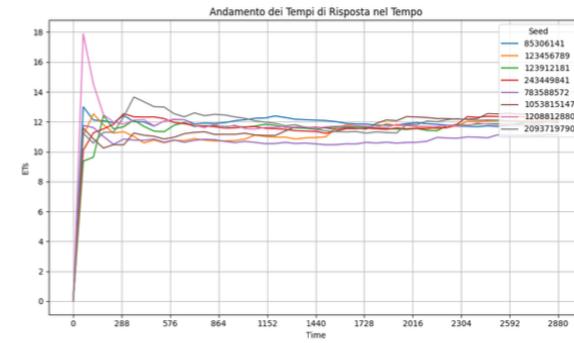
- ▶ Link repository Github: <https://github.com/NicolaViolante/BoltSimulator.git>

# PRIMO OBIETTIVO

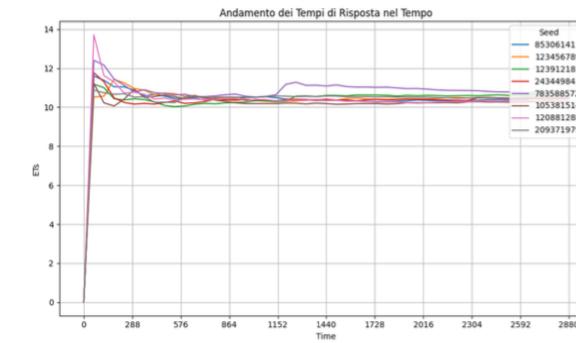
# Analisi del transitorio: configurazione [(24-5-12), (9-1-4)]



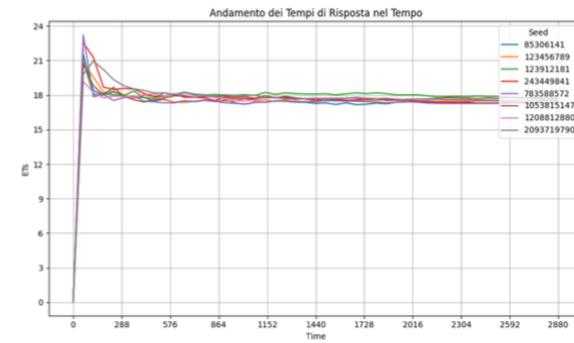
(a) Centro small



(b) Centro medium



(c) Centro large

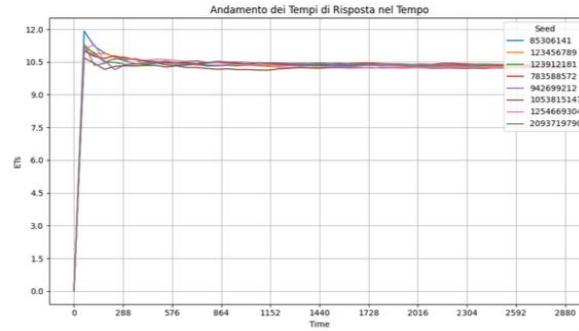
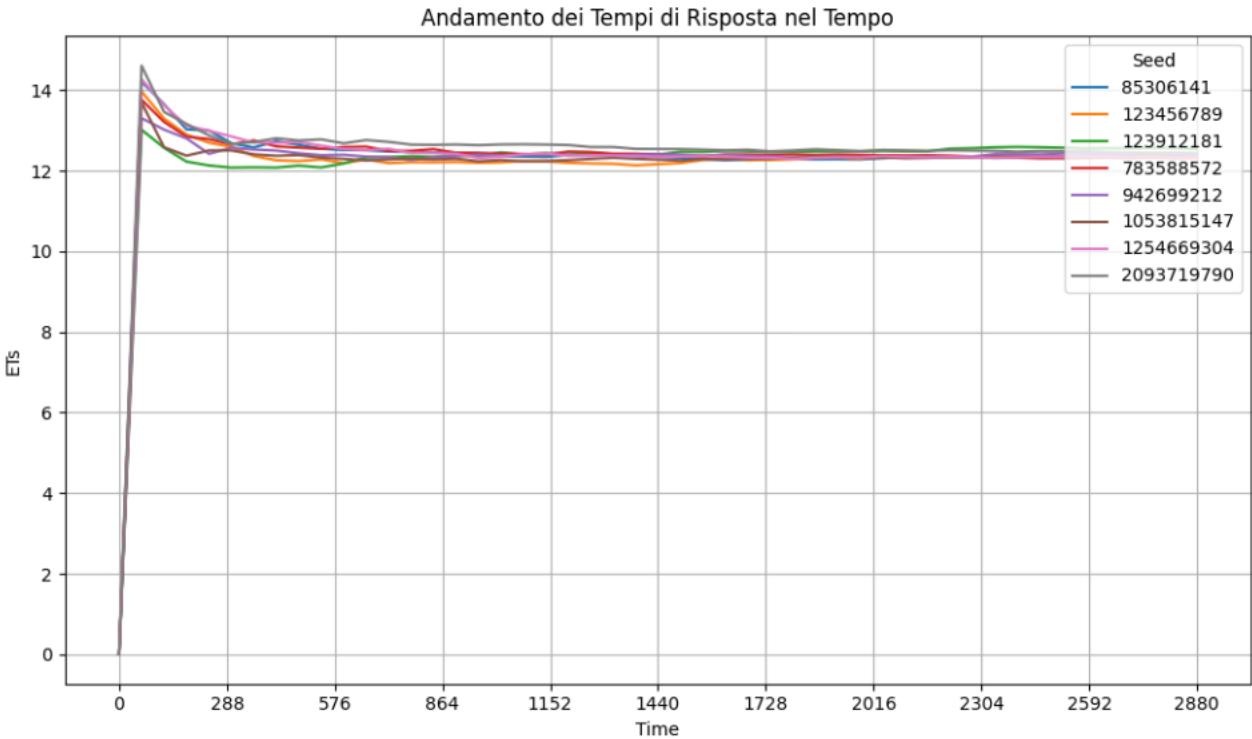


(d) Centro ride-sharing

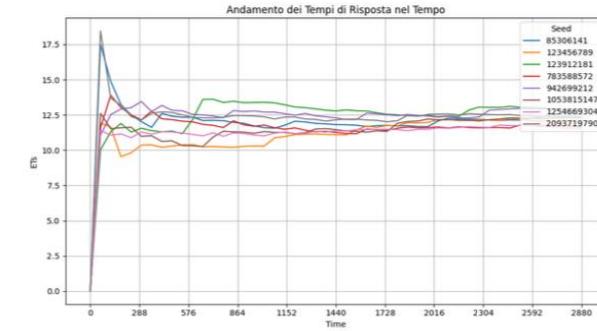
**SISTEMA**

**CENTRI**

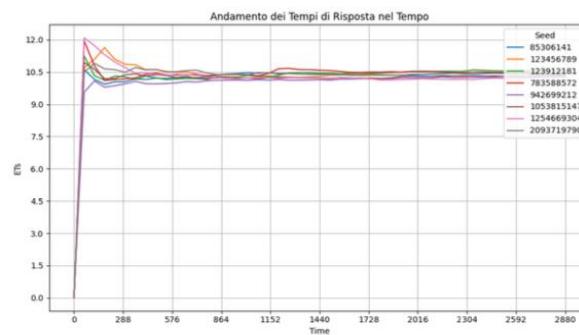
# Analisi del transitorio: configurazione [(25-5-13), (8-1-3)]



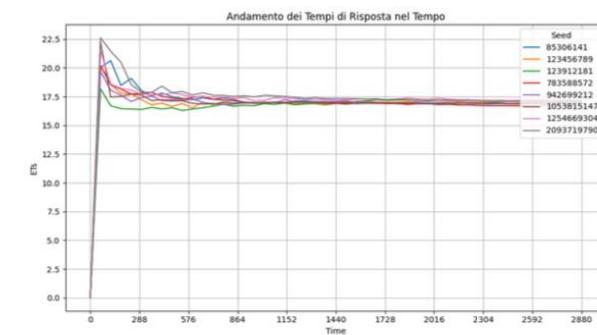
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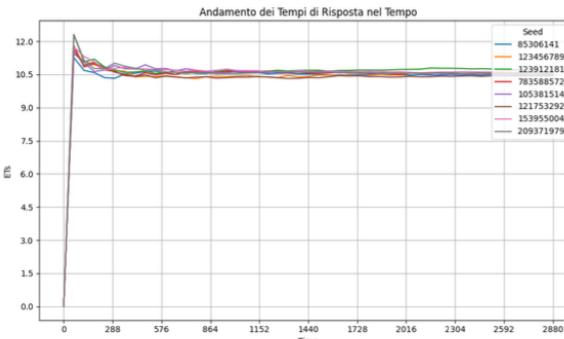
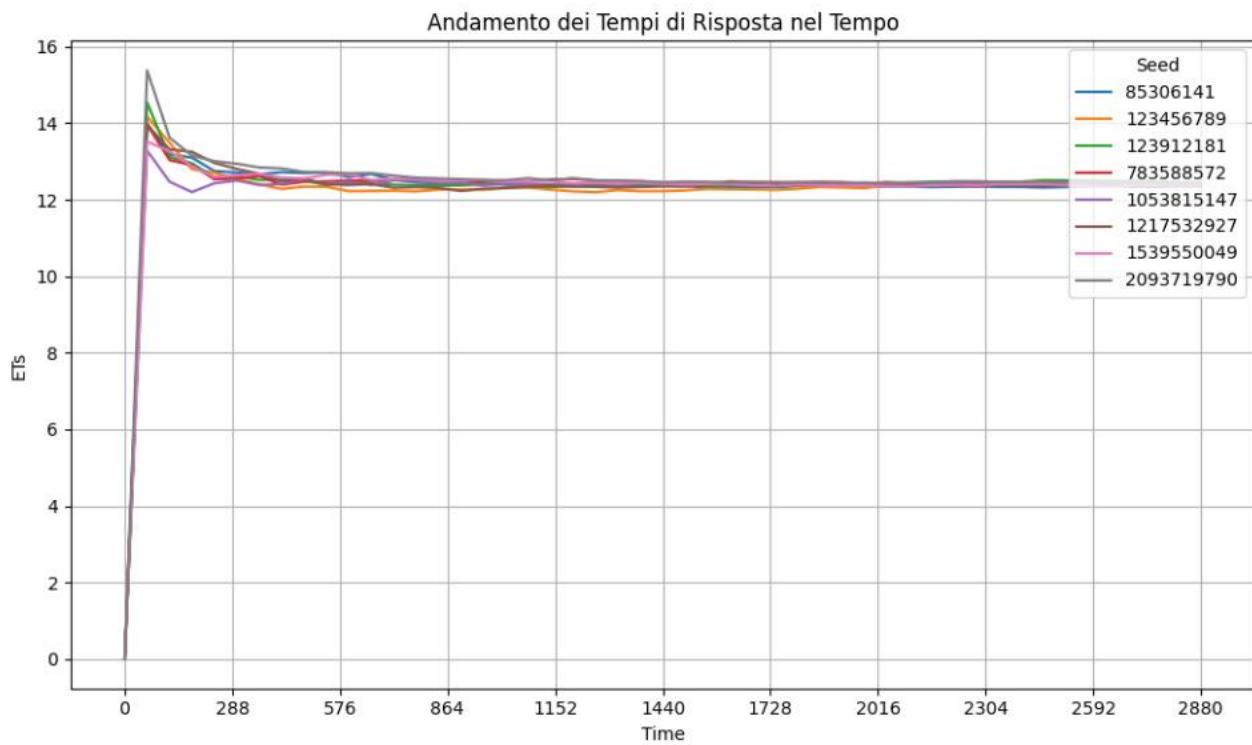


(d) Centro ride-sharing

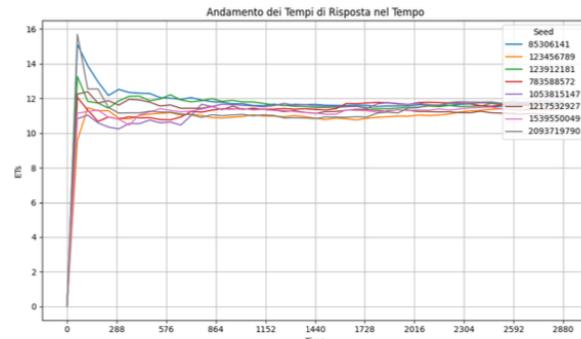
**SISTEMA**

**CENTRI**

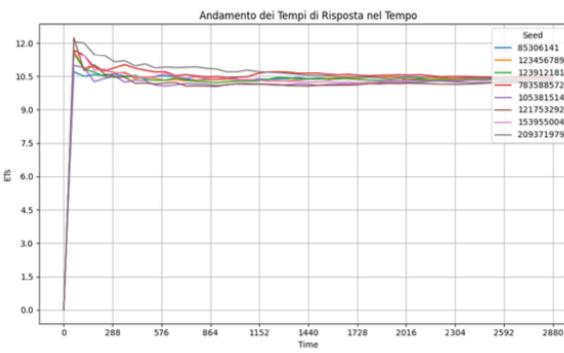
# Analisi del transitorio: configurazione [(27-6-13), (6-0-3)]



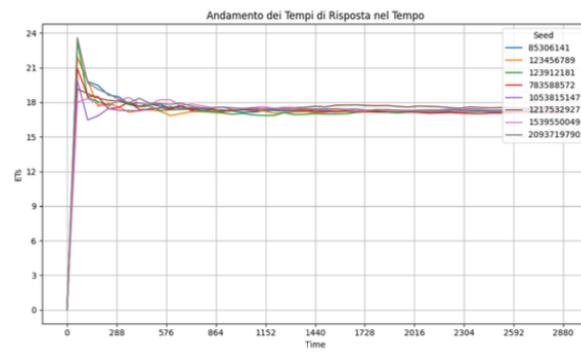
(a) Centro small



(b) Centro medium



(c) Centro large



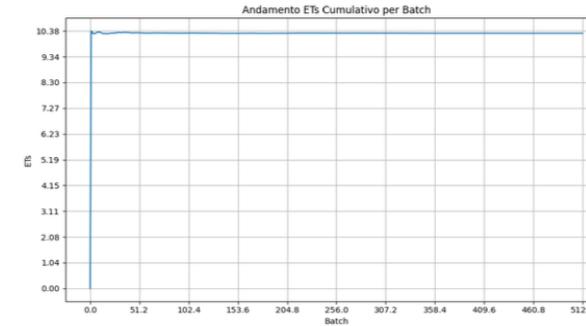
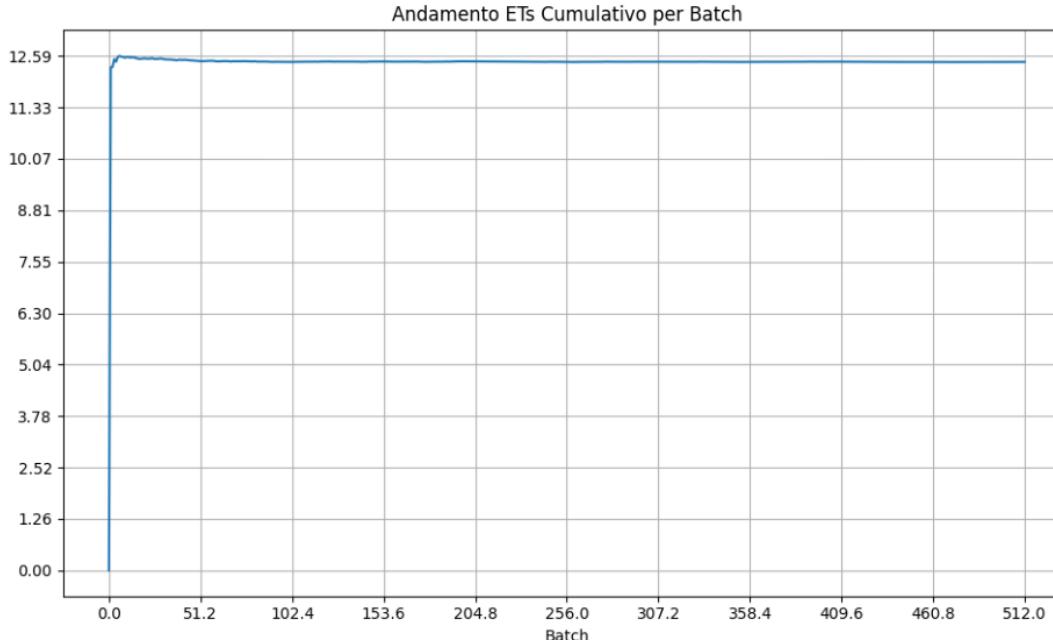
(d) Centro ride-sharing

**SISTEMA**

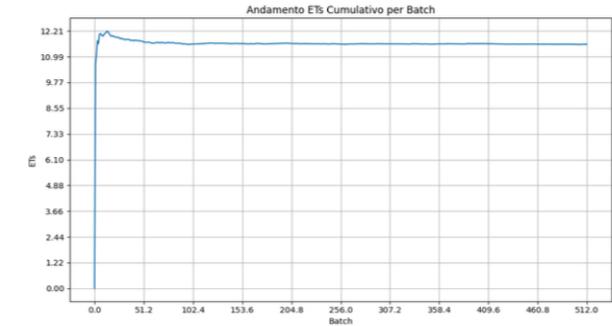
**CENTRI**

# Simulazione a orizzonte infinito: configurazione [(24-5-12), (9-1-4)]

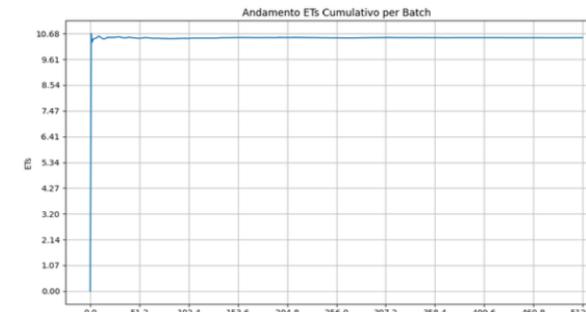
- ▶ b: 2048
- ▶ k: 512



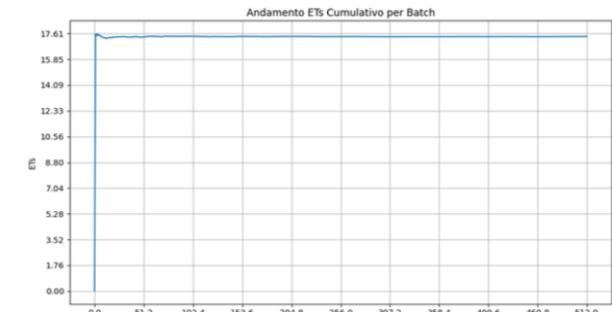
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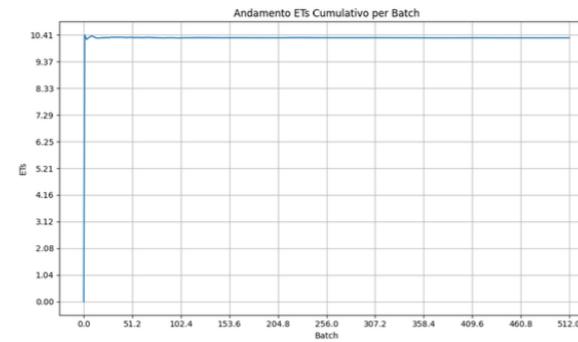
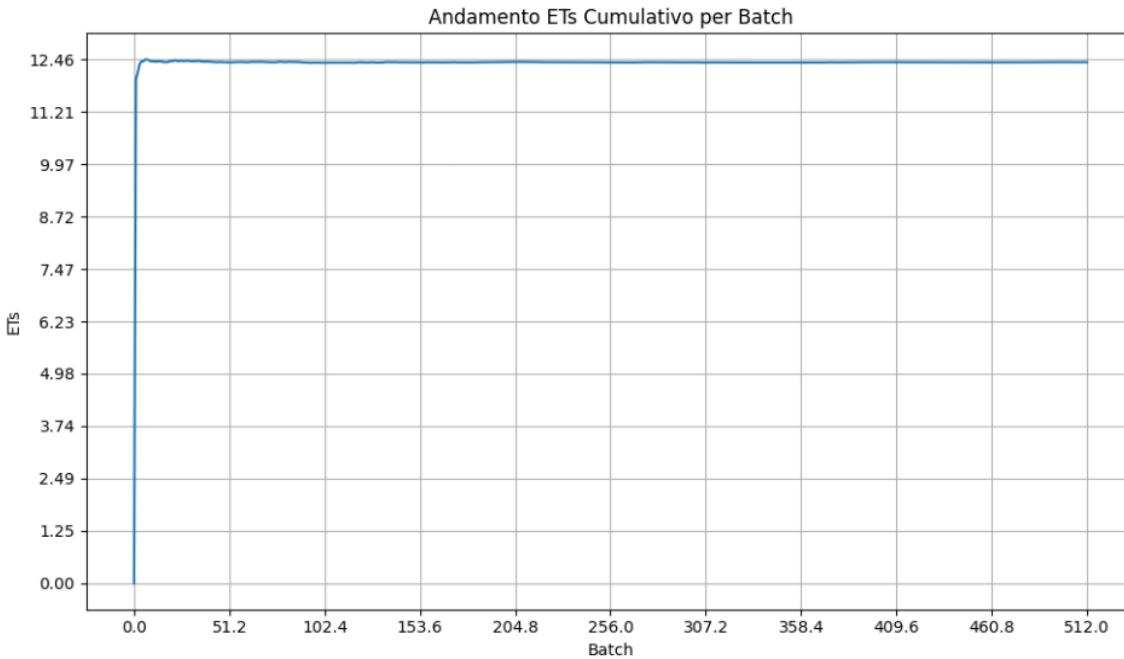


(d) Centro ride-sharing

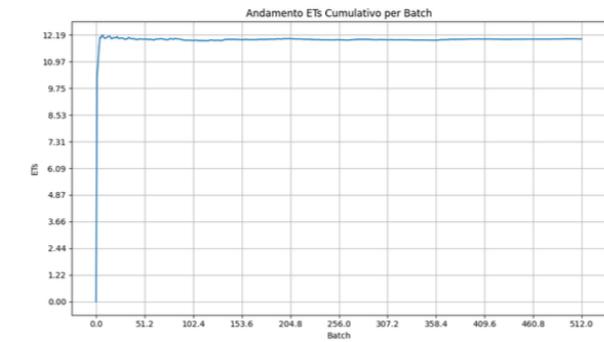
Centro	$E[N_S]$	$E[T_S]$	$E[N_Q]$	$E[T_Q]$	$\rho$	$E[S_i]$	$\lambda$
small	$16.6780 \pm 0.0582$	$10.2854 \pm 0.0128$	$0.0989 \pm 0.0095$	$0.0600 \pm 0.0056$	$0.6908 \pm 0.0022$	$10.2254 \pm 0.01165$	$1.6214 \pm 0.0048$
medium	$3.5547 \pm 0.0417$	$11.5754 \pm 0.0747$	$0.3002 \pm 0.0195$	$0.9524 \pm 0.0563$	$0.6509 \pm 0.0052$	$10.6230 \pm 0.0311$	$0.3063 \pm 0.0021$
large	$8.4705 \pm 0.0448$	$10.5063 \pm 0.0264$	$0.2295 \pm 0.0133$	$0.2811 \pm 0.0156$	$0.6868 \pm 0.0030$	$10.2253 \pm 0.0175$	$0.8060 \pm 0.0033$
ride-sharing	$19.5314 \pm 0.0657$	$17.4111 \pm 0.0351$	$3.1704 \pm 0.0125$	$2.8263 \pm 0.0083$	$0.4177 \pm 0.0138$	$14.5848 \pm 0.0330$	$1.1222 \pm 0.0041$

# Simulazione a orizzonte infinito: configurazione [(25-5-13), (8-1-3)]

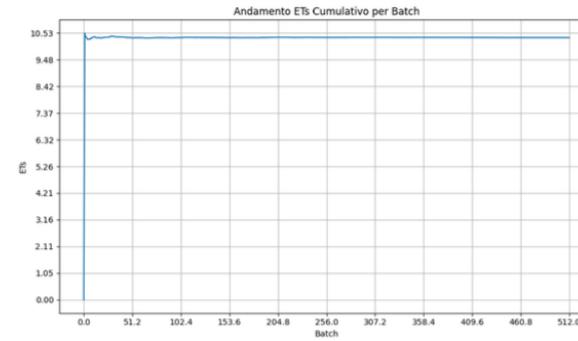
- b: 2048
- k: 512



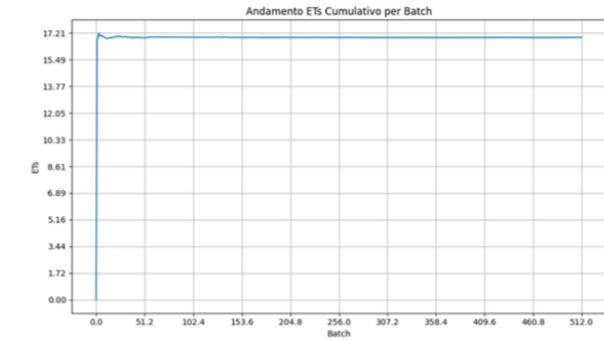
(a) Centro small



(b) Centro medium



(c) Centro large

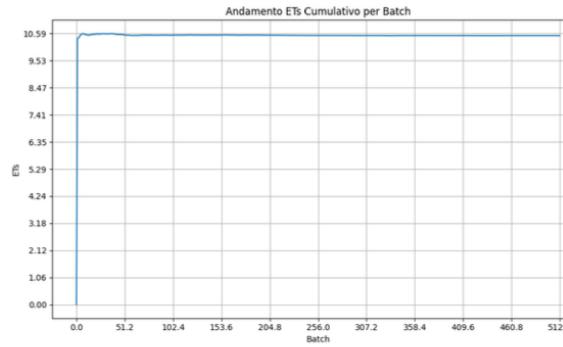
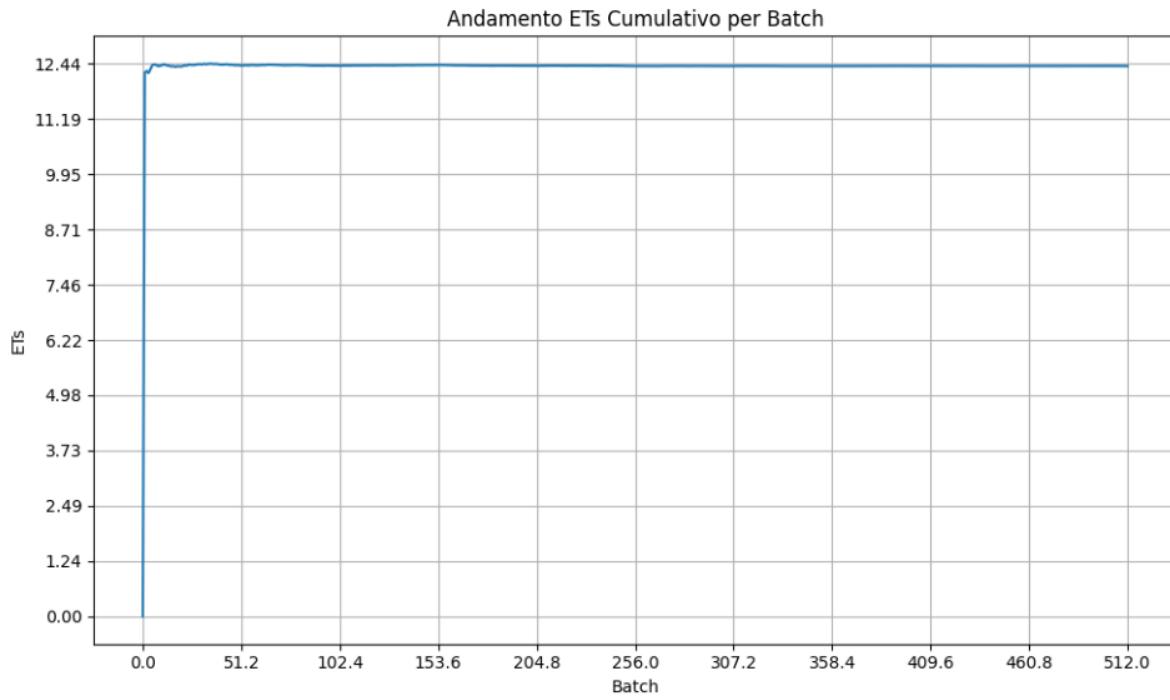


(d) Centro ride-sharing

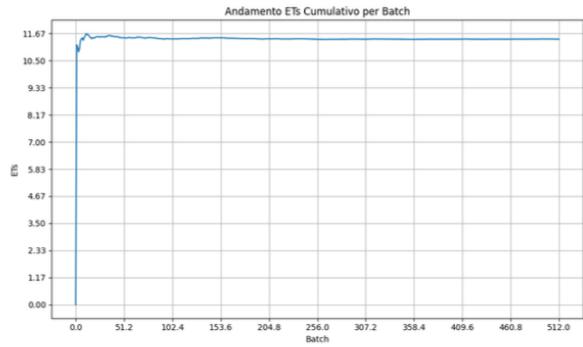
Centro	$E[N_S]$	$E[T_S]$	$E[N_Q]$	$E[T_Q]$	$\rho$	$E[S_i]$	$\lambda$
small	$16.7830 \pm 0.0590$	$10.2985 \pm 0.0138$	$0.0607 \pm 0.0068$	$0.0366 \pm 0.0040$	$0.6689 \pm 0.0022$	$10.2619 \pm 0.0127$	$1.6295 \pm 0.0049$
medium	$3.8779 \pm 0.0447$	$12.0008 \pm 0.0788$	$0.3913 \pm 0.0231$	$1.1814 \pm 0.0638$	$0.6973 \pm 0.0051$	$10.8194 \pm 0.0316$	$0.3222 \pm 0.0021$
large	$8.3423 \pm 0.0400$	$10.3486 \pm 0.0205$	$0.1024 \pm 0.0073$	$0.1251 \pm 0.0087$	$0.6338 \pm 0.0028$	$10.2235 \pm 0.0170$	$0.8060 \pm 0.0033$
ride-sharing	$18.5727 \pm 0.0619$	$16.9296 \pm 0.0348$	$3.1699 \pm 0.0126$	$2.8895 \pm 0.0089$	$0.5024 \pm 0.0160$	$14.0400 \pm 0.0321$	$1.0975 \pm 0.0040$

# Simulazione a orizzonte infinito: configurazione [(27-6-13), (6-0-3)]

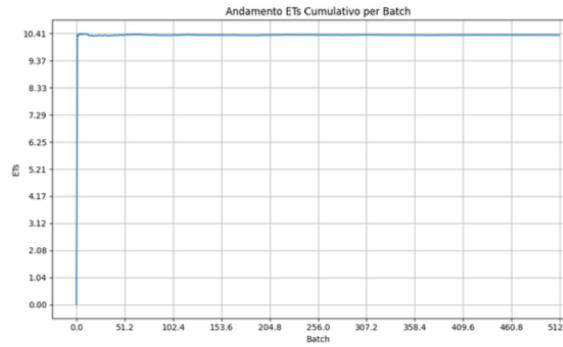
- b: 2048
- k: 512



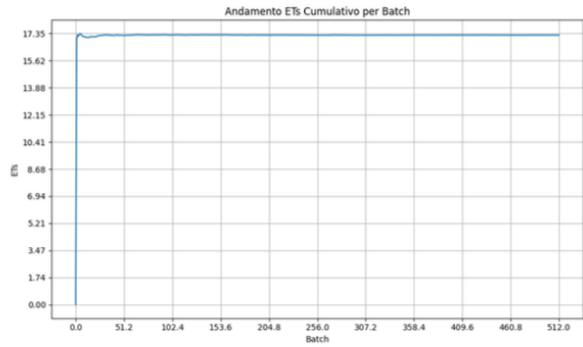
(a) Centro small



(b) Centro medium



(c) Centro large



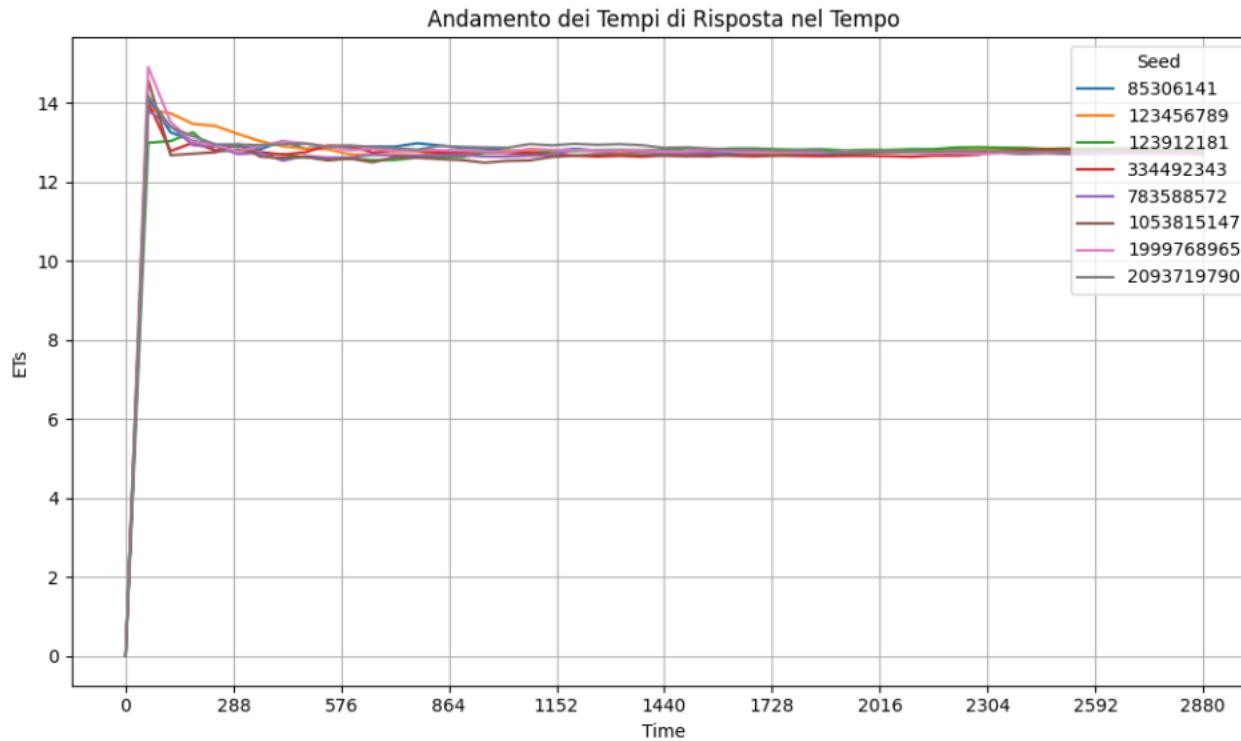
(d) Centro ride-sharing

Centro	$E[N_S]$	$E[T_S]$	$E[N_Q]$	$E[T_Q]$	$\rho$	$E[S_i]$	$\lambda$
small	$17.6455 \pm 0.0640$	$10.5059 \pm 0.0174$	$0.0342 \pm 0.0038$	$0.0201 \pm 0.0022$	$0.6523 \pm 0.0023$	$10.4858 \pm 0.0168$	$1.6794 \pm 0.0049$
medium	$3.8197 \pm 0.0355$	$11.4241 \pm 0.0497$	$0.1501 \pm 0.0104$	$0.4365 \pm 0.0281$	$0.6116 \pm 0.0047$	$10.9876 \pm 0.0324$	$0.3338 \pm 0.0022$
large	$8.3488 \pm 0.0413$	$10.3552 \pm 0.0206$	$0.1037 \pm 0.0072$	$0.1268 \pm 0.0085$	$0.6342 \pm 0.0029$	$10.2284 \pm 0.0170$	$0.8061 \pm 0.0034$
ride-sharing	$17.8600 \pm 0.0524$	$17.2511 \pm 0.0378$	$3.1693 \pm 0.0123$	$3.0612 \pm 0.0099$	$0.6335 \pm 0.0188$	$14.1900 \pm 0.0341$	$1.0357 \pm 0.0033$

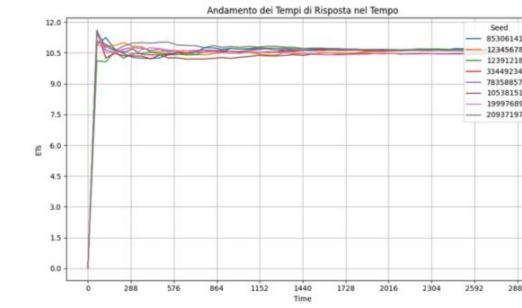
# SECONDO OBIETTIVO

# Analisi del transitorio

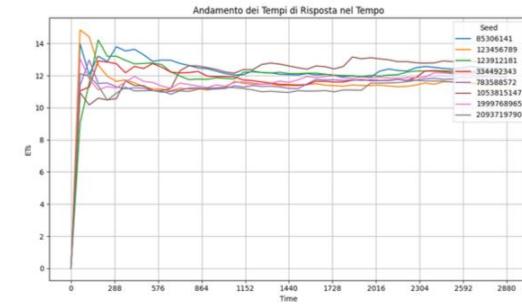
- ▶ Configurazione: [(23, 5, 11), (5, 0, 4)]



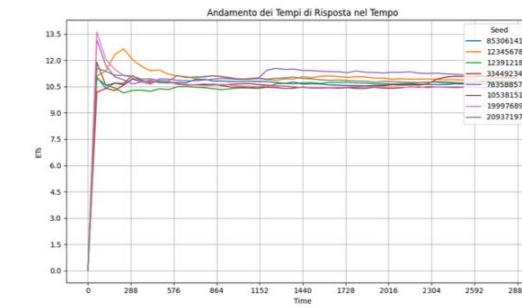
**SISTEMA**



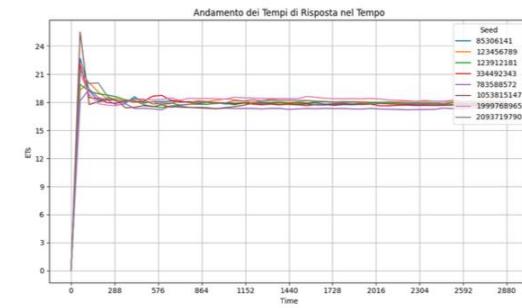
(a) Centro small



(b) Centro medium



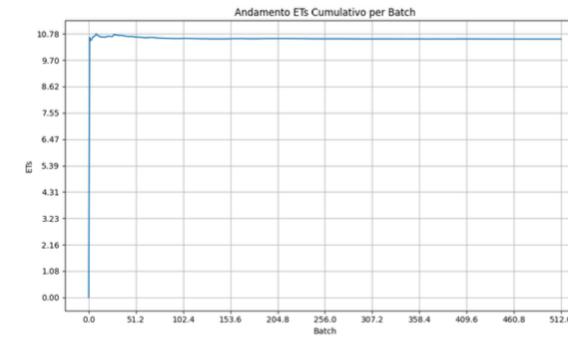
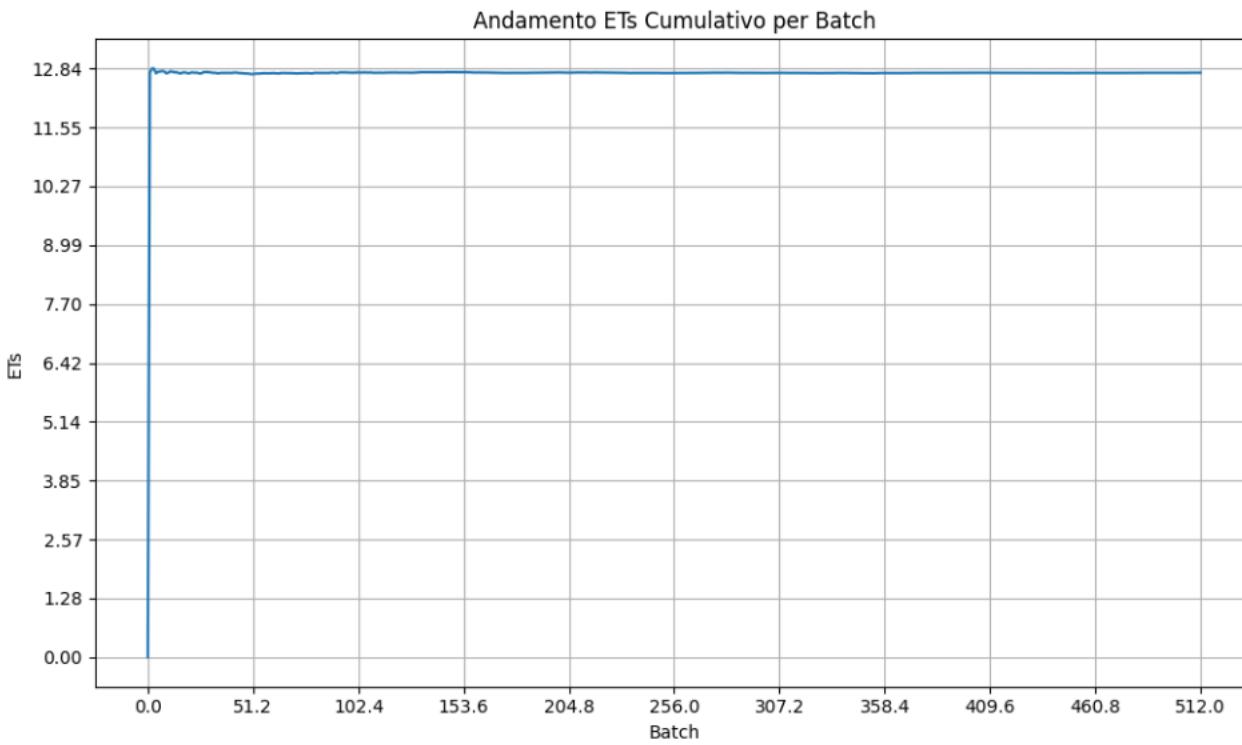
(c) Centro large



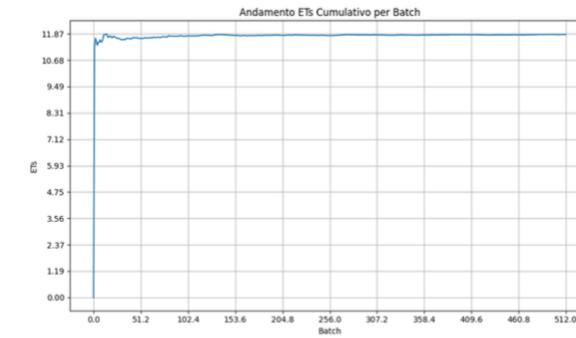
(d) Centro ride-sharing

**CENTRI**

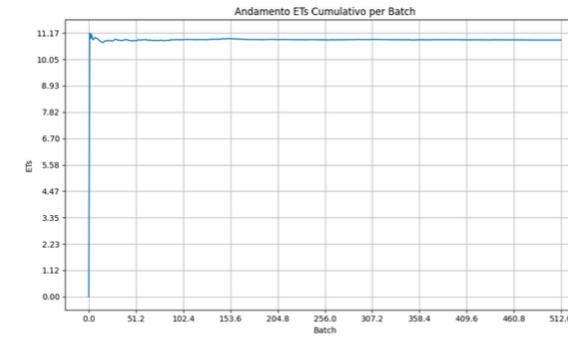
# Simulazione a orizzonte infinito



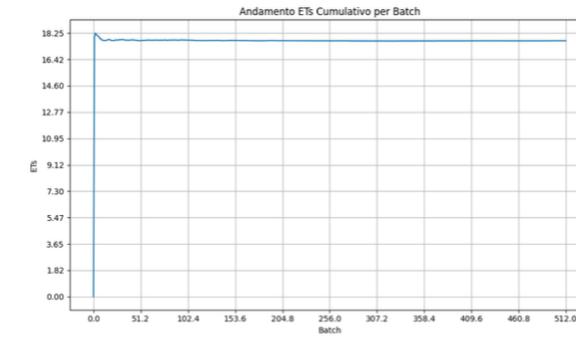
(a) Centro small



(b) Centro medium



(c) Centro large



(d) Centro ride-sharing

Centro	$E[N_S]$	$E[T_S]$	$E[N_Q]$	$E[T_Q]$	$\rho$	$E[S_i]$	$\lambda$
small	$17.5685 \pm 0.0740$	$10.5657 \pm 0.0224$	$0.2658 \pm 0.0220$	$0.1577 \pm 0.0125$	$0.7523 \pm 0.0026$	$10.4081 \pm 0.0155$	$1.6623 \pm 0.0048$
medium	$3.7619 \pm 0.0458$	$11.8403 \pm 0.0810$	$0.3632 \pm 0.0232$	$1.1116 \pm 0.0646$	$0.6797 \pm 0.0053$	$10.7287 \pm 0.0322$	$0.3167 \pm 0.0022$
large	$8.7670 \pm 0.0593$	$10.8689 \pm 0.0411$	$0.5232 \pm 0.0292$	$0.6389 \pm 0.0336$	$0.7494 \pm 0.0032$	$10.2300 \pm 0.0164$	$0.8058 \pm 0.0032$
ride-sharing	$18.9584 \pm 0.0541$	$17.7150 \pm 0.0377$	$3.1700 \pm 0.0123$	$2.9618 \pm 0.0092$	$0.6146 \pm 0.0174$	$14.7533 \pm 0.0346$	$1.0706 \pm 0.0034$

# Simulazione a orizzonte infinito

TIPOLOGIA	TRADIZIONALE	RIDE-SHARING	TOTALE
<b>SMALL</b>	23	5	28
<b>MEDIUM</b>	5	0	5
<b>LARGE</b>	11	4	15

► Riduzione complessiva da **55** a **48** veicoli: **-12.72%**

Modello base



Modello migliorativo



# Verifica e Validazione

## ► Verifica

- Controllo della coerenza delle statistiche raccolte

- $E[T_s] = E[T_Q] + E(S)$

- Legge di Little:

- $E[N_s] = \lambda E[T]$

- $E[N_Q] = \lambda E[T_Q]$

- Controllo specifico sull'interazione tra le due componenti

Centro	$\rho$
small	$0.6140 \pm 0.0018$
medium	$0.4583 \pm 0.0036$
large	$0.6328 \pm 0.0027$

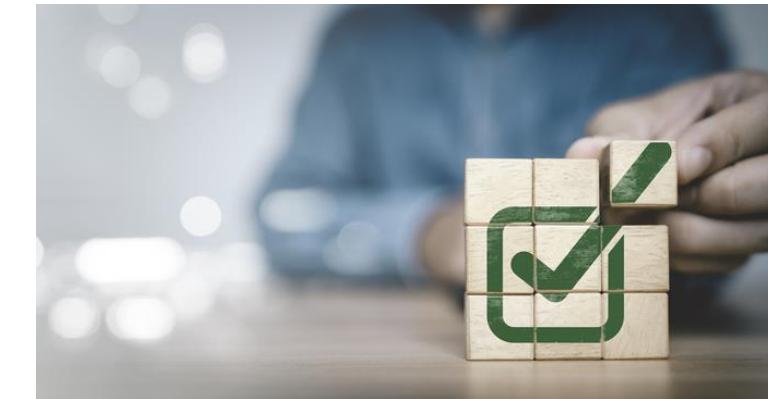
*Feedback disabilitato*

Centro	$\rho$
small	$0.6523 \pm 0.0023$
medium	$0.6116 \pm 0.0047$
large	$0.6342 \pm 0.0029$

*Feedback abilitato*

## ► Validazione

- **Non** possibile per mancanza di dati empirici e misurazioni del sistema reale



# SECONDA PARTE

# Simulazione a orizzonte infinito



- ▶ Suddivisione del carico in **5 fasi** ciascuna corrispondente ad una o più fasce orarie
- ▶ Ricerca della configurazione che **soddisfi i vincoli di qualità del servizio (QoS)**
  - ▶ Servizio tradizionale:  $E[TQ] \leq 3 \text{ min}$
  - ▶ Servizio di ride-sharing:  $E[TQ] \leq 7 \text{ min}$

## Traffico per fascia oraria:

- Diversi livelli di carico:

- *Very Low* →  $\lambda = 1$  rich/min
- *Low* →  $\lambda = 2$  rich/min
- *Medium* →  $\lambda = 3$  rich/min
- *High* →  $\lambda = 4$  rich/min
- *Very High* →  $\lambda = 5$  rich/min

- Fasce orarie principali:

03 : 00 – 05 : 00	05: 00 – 07: 00	07 : 00 – 09 : 00
09 : 00 – 14 : 00	14 : 00 – 16 : 00	16 : 00 – 19 : 00
19 : 00 – 22 : 00	22 : 00 – 00 : 00	00 : 00 – 03 : 00

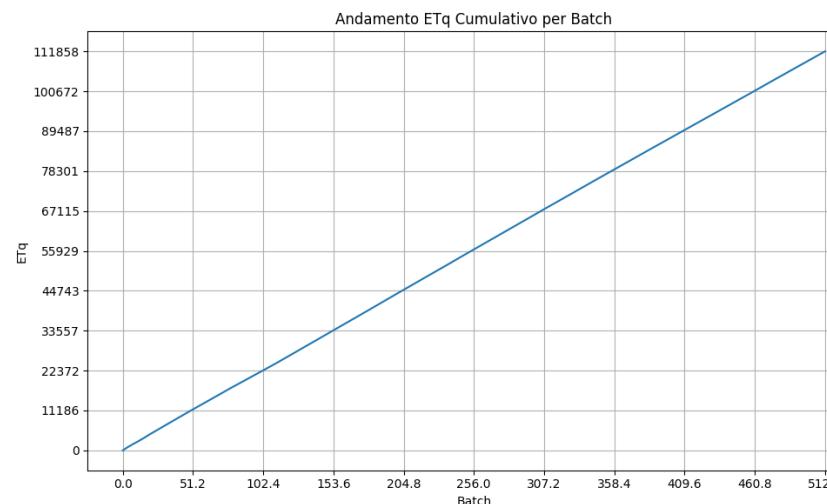
**Very Low:**

03 : 00 – 05 : 00

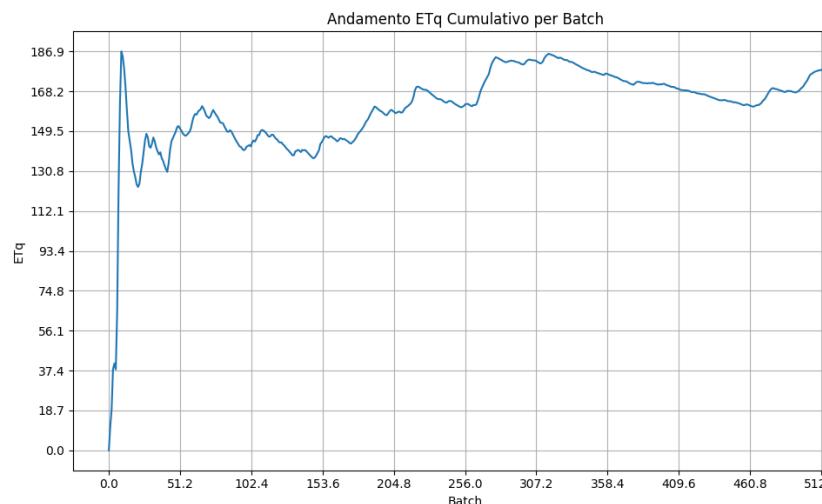
00 : 00 – 03 : 00

► Modello base:

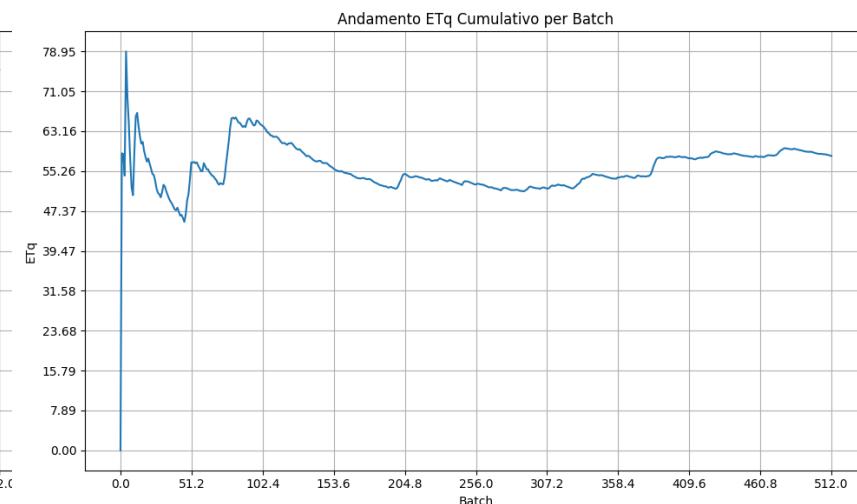
► Configurazione [5 ,1, 3] 



**CENTRO SMALL**



**CENTRO MEDIUM**



**CENTRO LARGE**

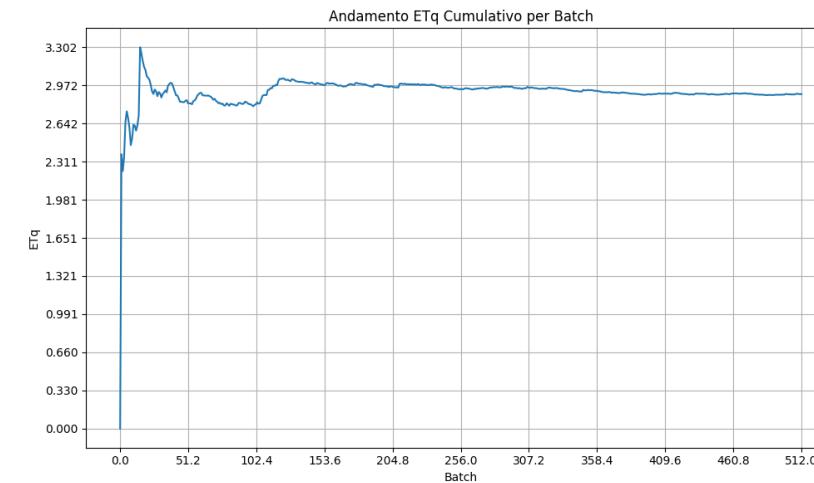
**Very Low:**

03 : 00 – 05 : 00

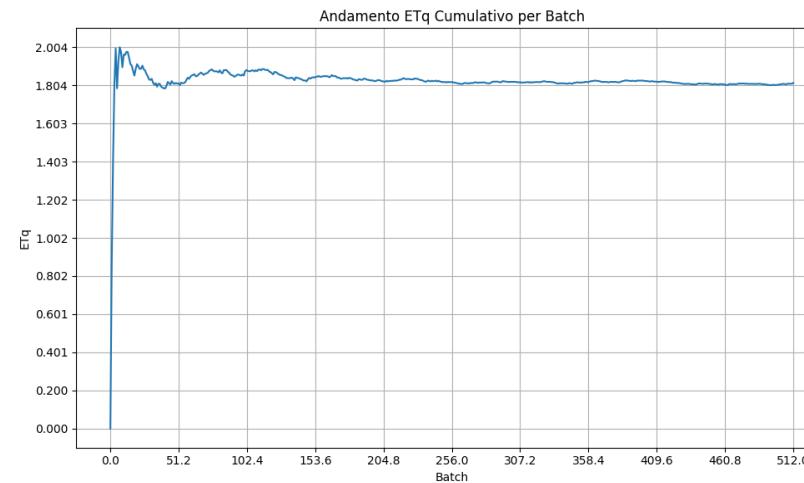
00 : 00 – 03 : 00

► Modello base:

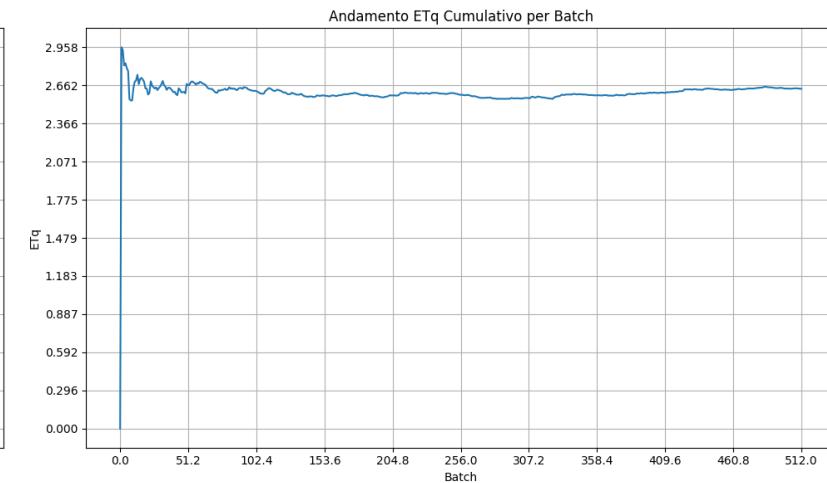
► Configurazione [7 ,2 ,4 ] ✓



**CENTRO SMALL**



**CENTRO MEDIUM**



**CENTRO LARGE**

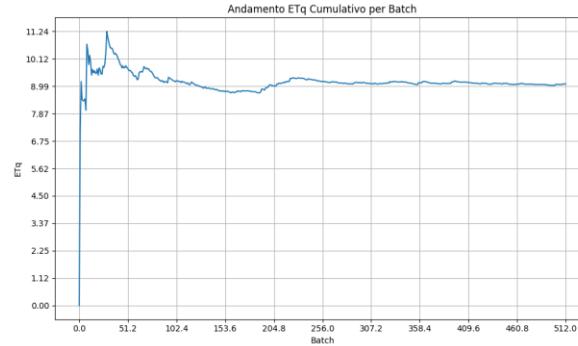
**Very Low:**

03 : 00 – 05 : 00

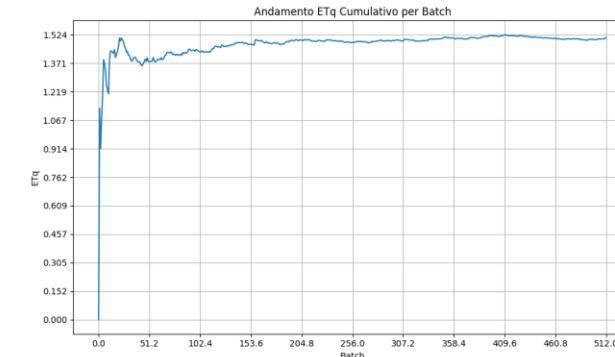
00 : 00 – 03 : 00

► **Modello migliorativo:**

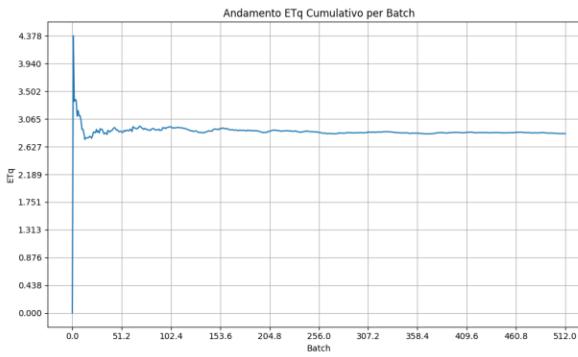
► Configurazione [5,2,3] [2,0,1] 



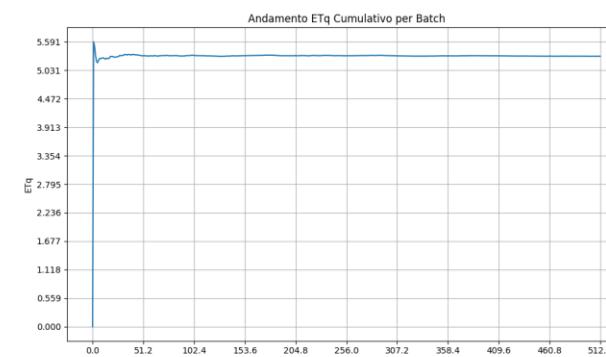
**CENTRO SMALL**



**CENTRO MEDIUM**



**CENTRO LARGE**



**CENTRO RIDE**

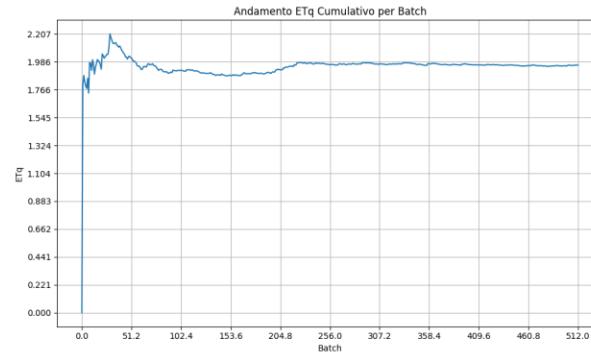
**Very Low:**

03 : 00 – 05 : 00

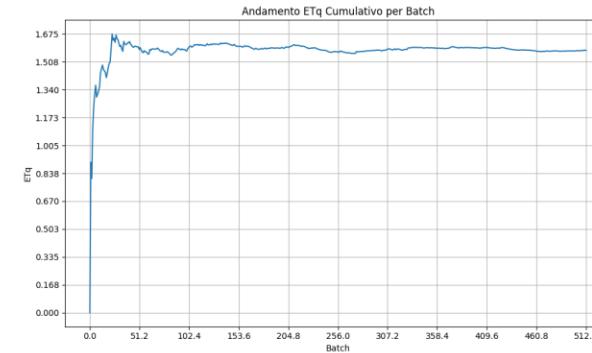
00 : 00 – 03 : 00

► **Modello migliorativo:**

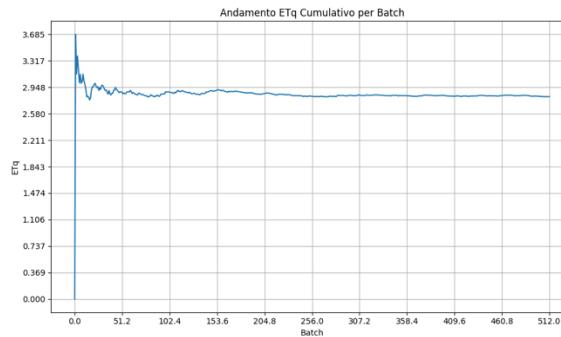
► Configurazione [6,2,3] [2,0,1] ✓



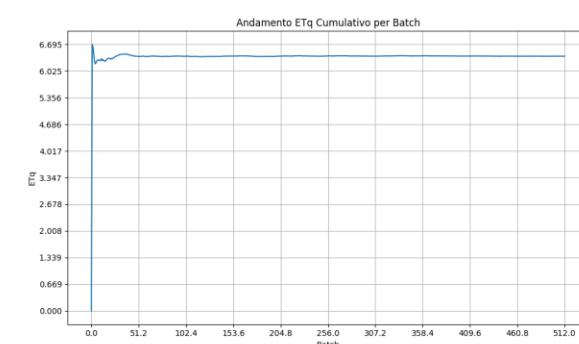
**CENTRO SMALL**



**CENTRO MEDIUM**



**CENTRO LARGE**



**CENTRO RIDE**

**Low:**

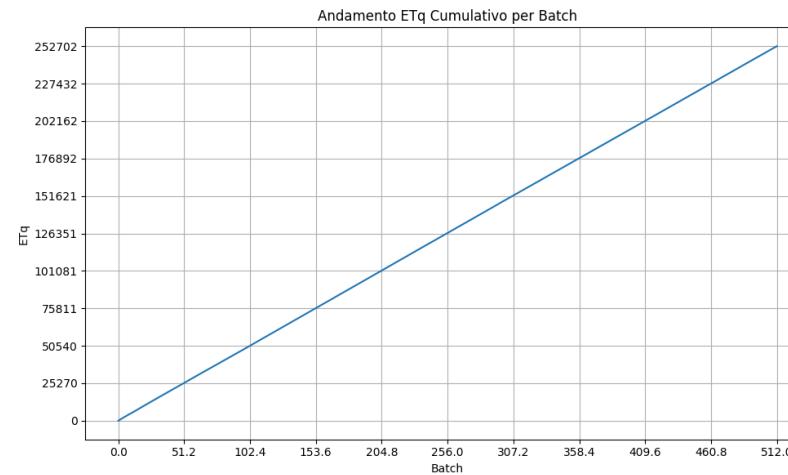
**05 : 00 – 07 : 00**

**14 : 00 – 16 : 00**

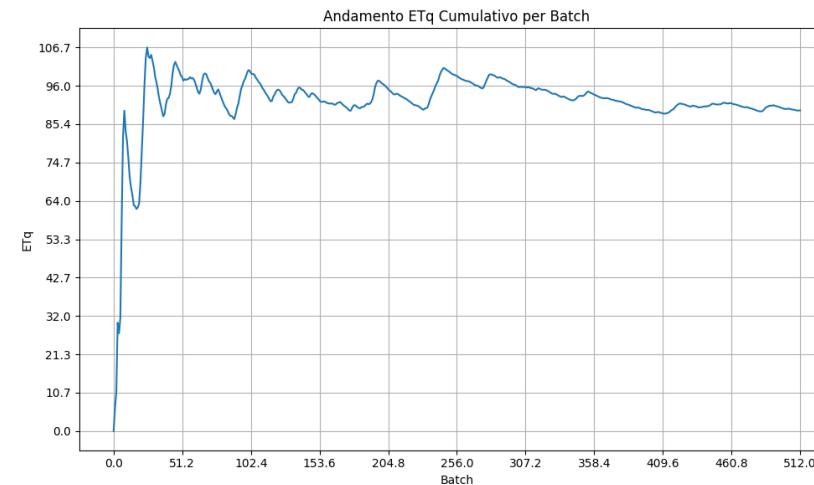
**22 : 00 – 00 : 00**

► **Modello base:**

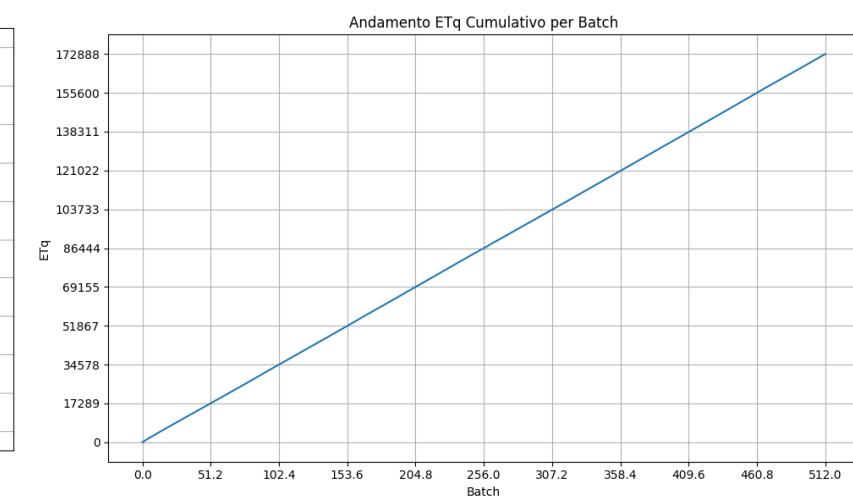
► **Configurazione [7,2,4] X**



**CENTRO SMALL**



**CENTRO MEDIUM**



**CENTRO LARGE**

**Low:**

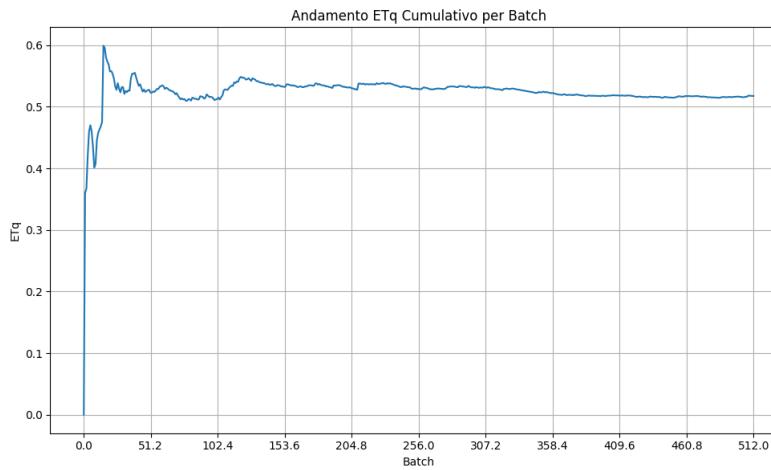
**05: 00 – 07: 00**

**14 : 00 – 16 : 00**

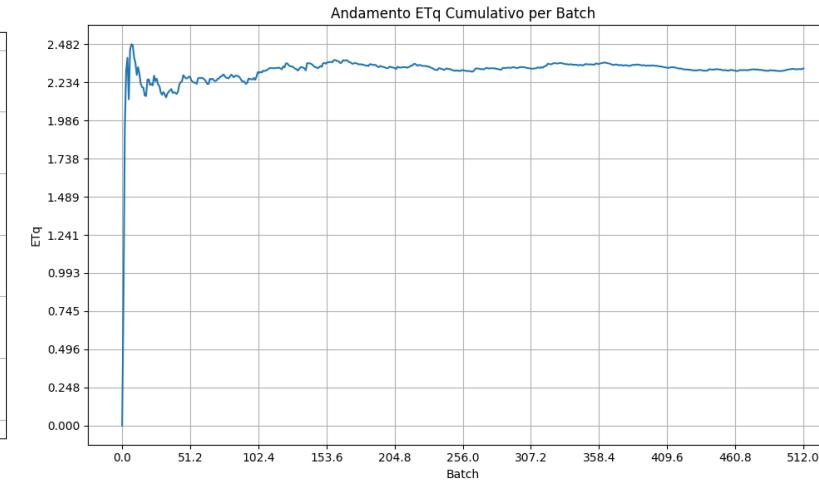
**22 : 00 – 00 : 00**

► **Modello base:**

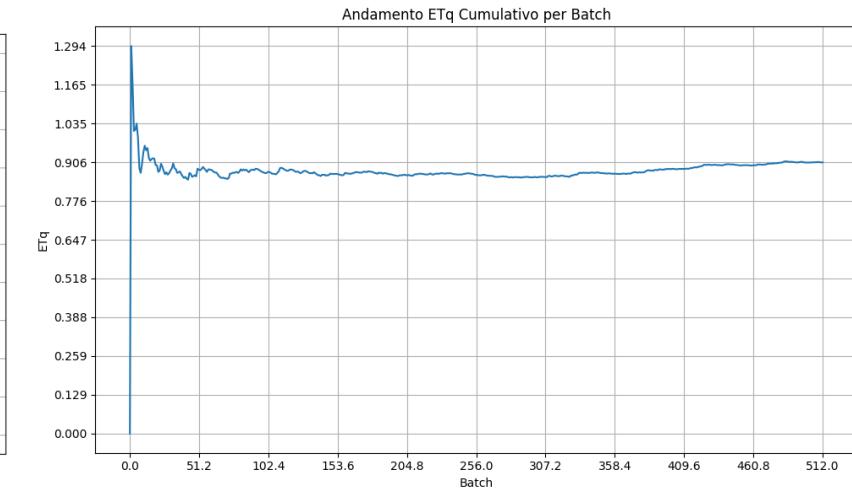
► **Configurazione [15,3,8] ✓**



**CENTRO SMALL**



**CENTRO MEDIUM**



**CENTRO LARGE**

**Low:**

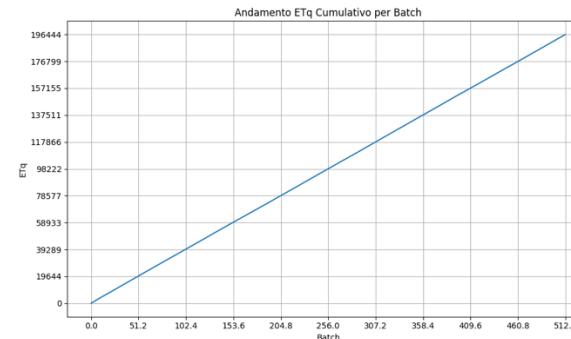
**05: 00 – 07: 00**

**14 : 00 – 16 : 00**

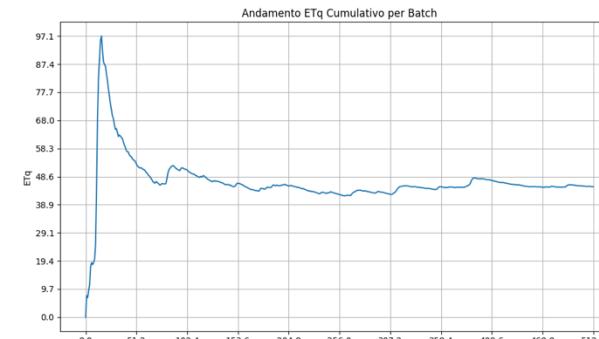
**22 : 00 – 00 : 00**

► **Modello migliorativo:**

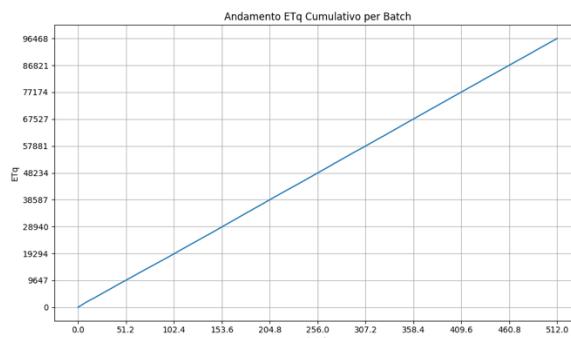
► Configurazione [6,2,3] [2,0,1] 



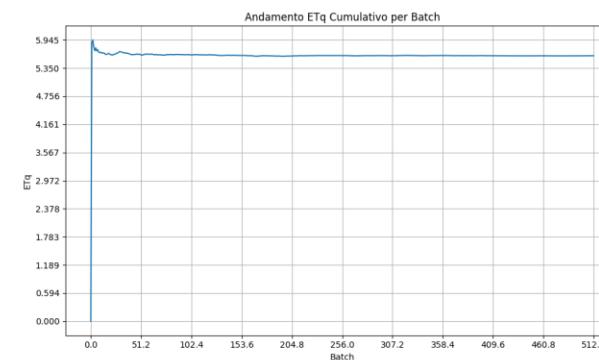
**CENTRO SMALL**



**CENTRO MEDIUM**



**CENTRO LARGE**



**CENTRO RIDE**

**Low:**

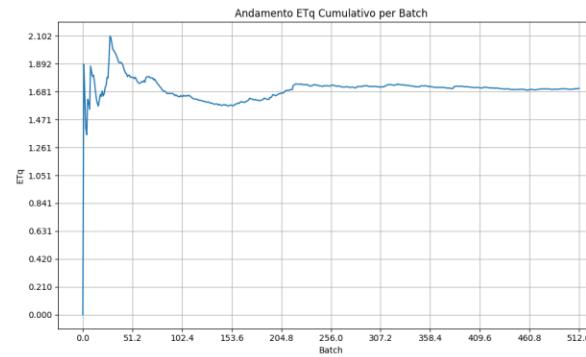
**05: 00 – 07: 00**

**14 : 00 – 16 : 00**

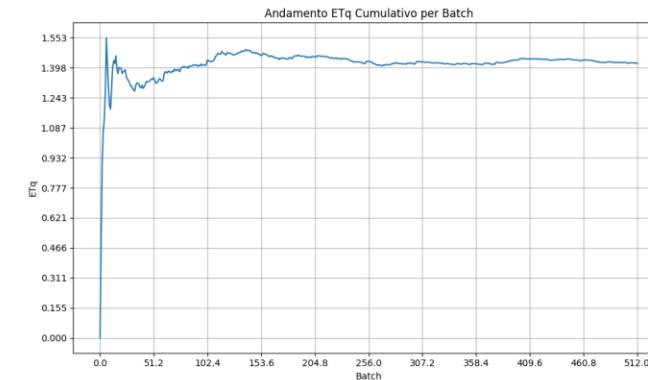
**22 : 00 – 00 : 00**

► **Modello migliorativo:**

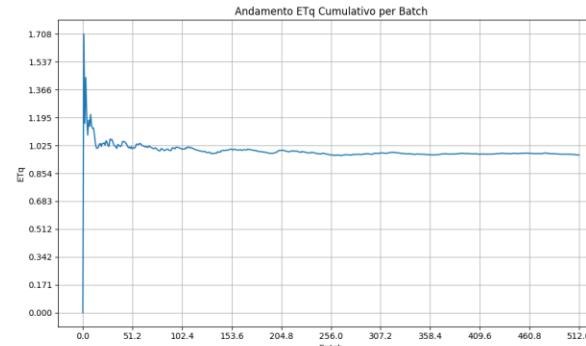
- Configurazione **[10,3,6] [5,0,2]** ✓



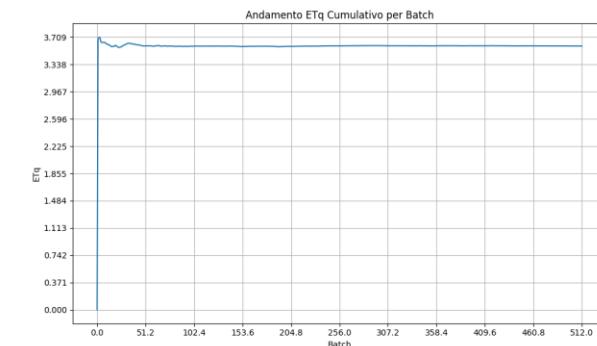
**CENTRO SMALL**



**CENTRO MEDIUM**



**CENTRO LARGE**



**CENTRO RIDE**

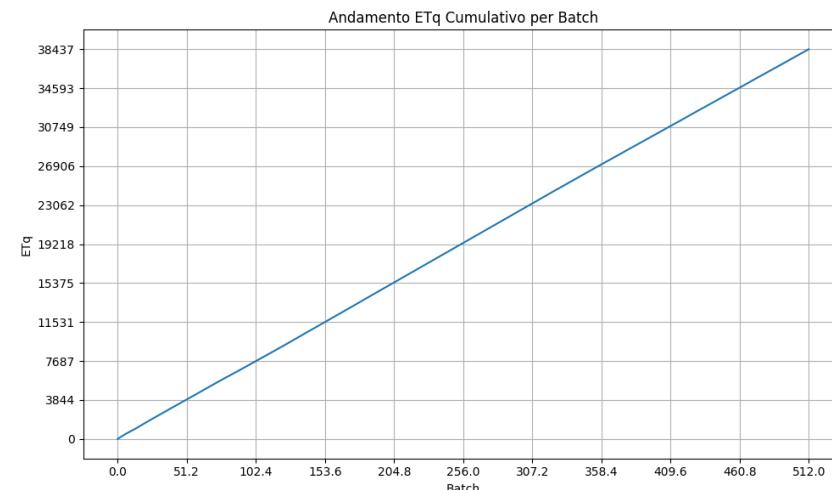
**Medium:**

09 : 00 – 14 : 00

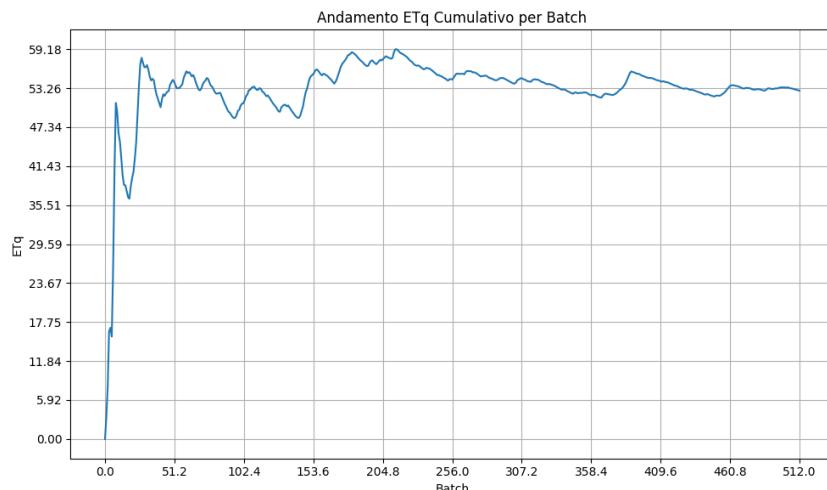
19 : 00 – 22 : 00

► Modello base:

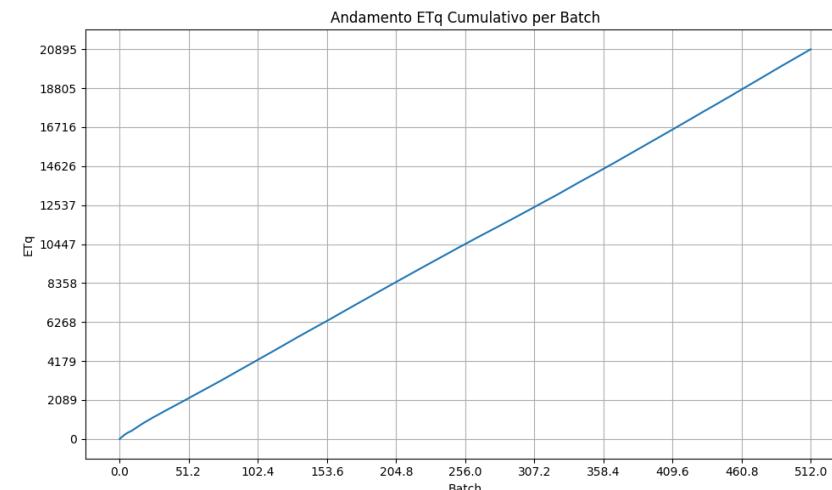
► Configurazione [15,3,8] 



**CENTRO SMALL**



**CENTRO MEDIUM**



**CENTRO LARGE**

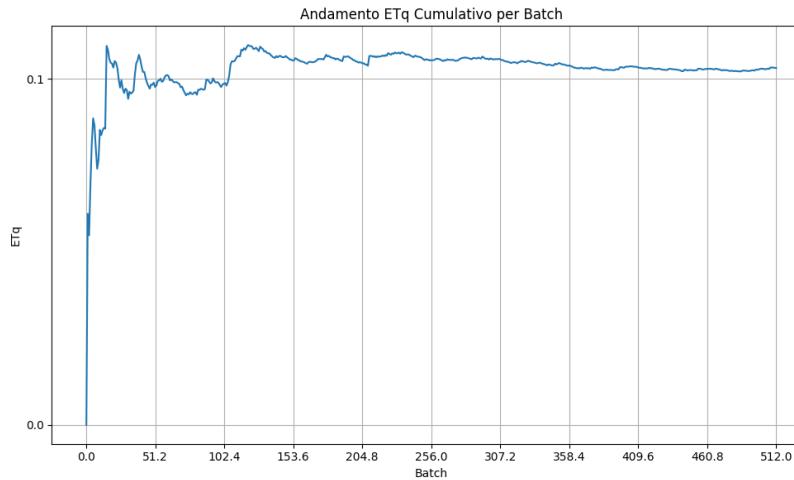
**Medium:**

09 : 00 – 14 : 00

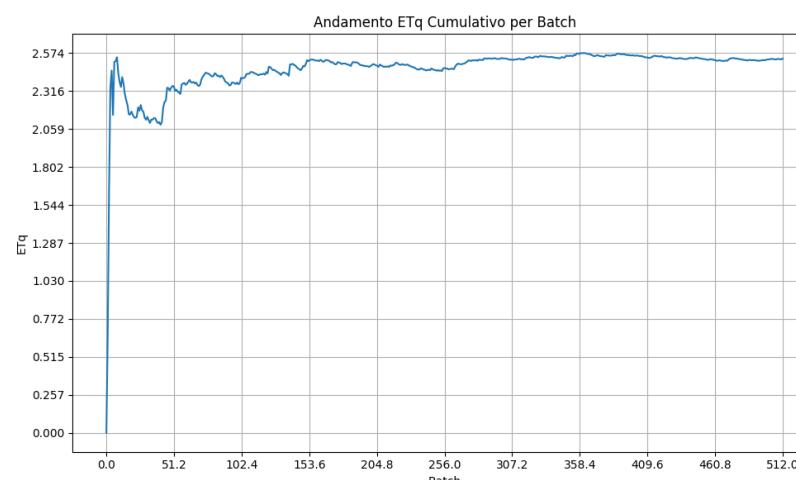
19 : 00 – 22 : 00

► Modello base:

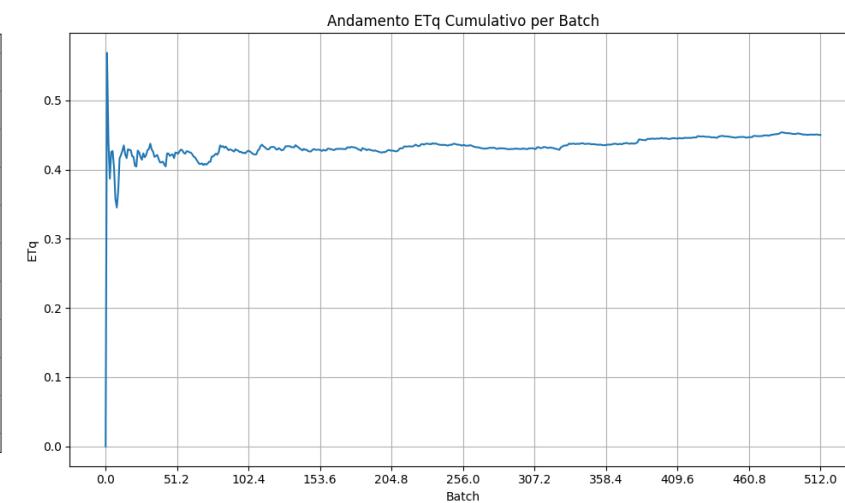
► Configurazione [24 ,4 ,12] ✓



CENTRO SMALL



CENTRO MEDIUM



CENTRO LARGE

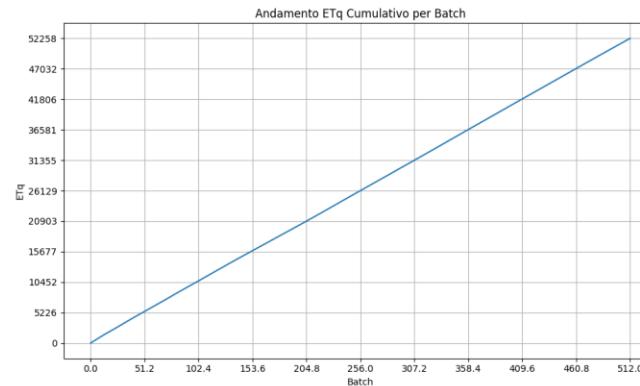
**Medium:**

09 : 00 – 14 : 00

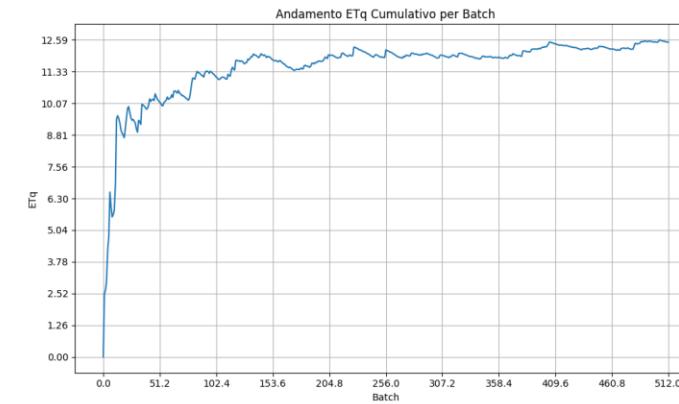
19 : 00 – 22 : 00

► **Modello migliorativo:**

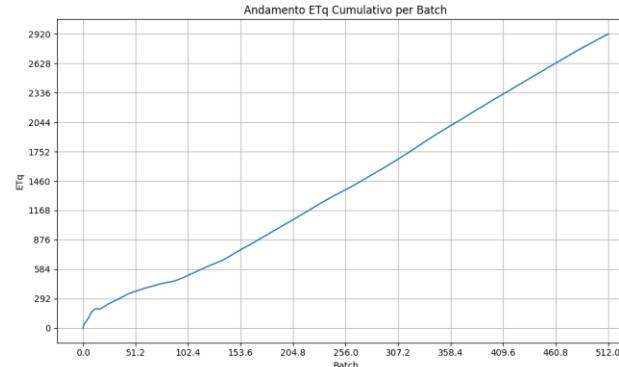
► Configurazione [10,3,6] [5,0,2] 



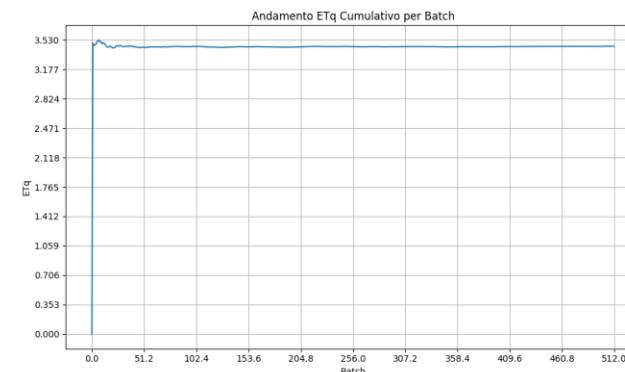
**CENTRO SMALL**



**CENTRO MEDIUM**



**CENTRO LARGE**



**CENTRO RIDE**

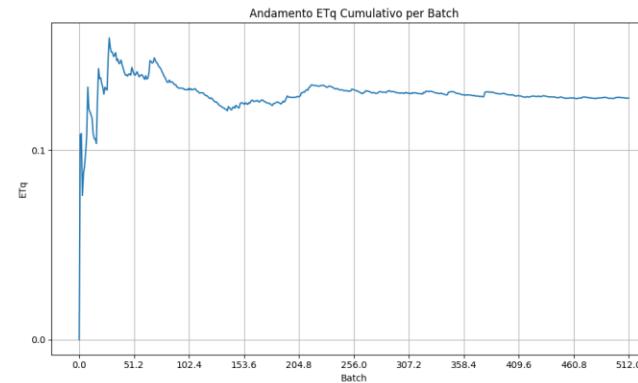
**Medium:**

**09 : 00 – 14 : 00**

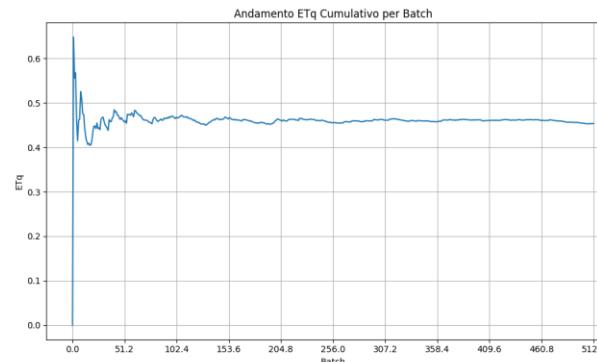
**19 : 00 – 22 : 00**

► **Modello migliorativo:**

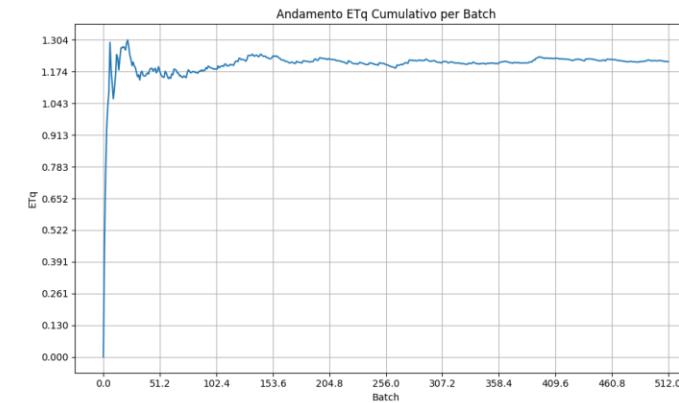
► Configurazione **[18,4,9] [6,0,3]** ✓



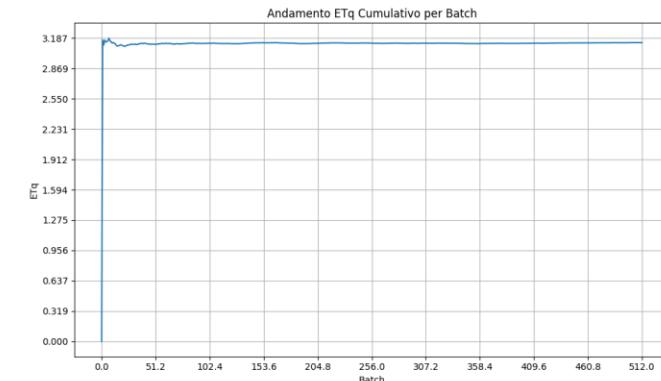
**CENTRO SMALL**



**CENTRO LARGE**



**CENTRO MEDIUM**



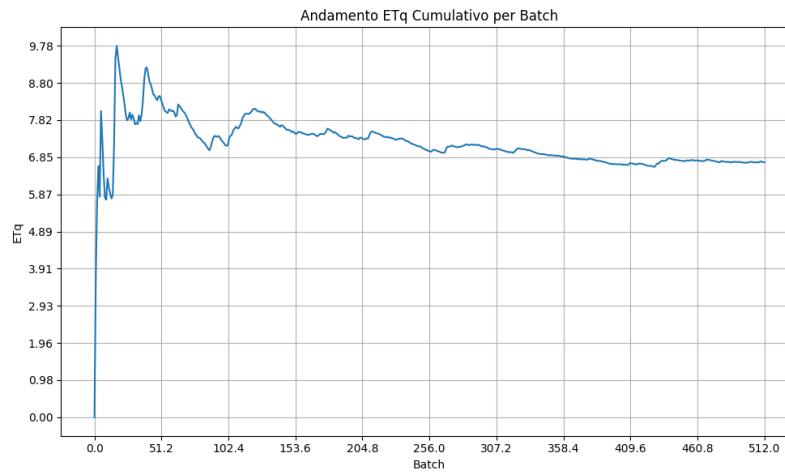
**CENTRO RIDE**

**High:**

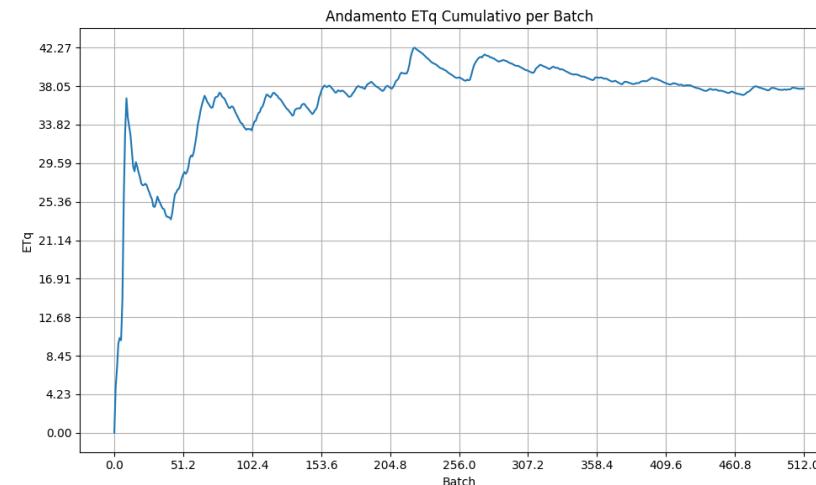
16 : 00 – 19 : 00

► Modello base:

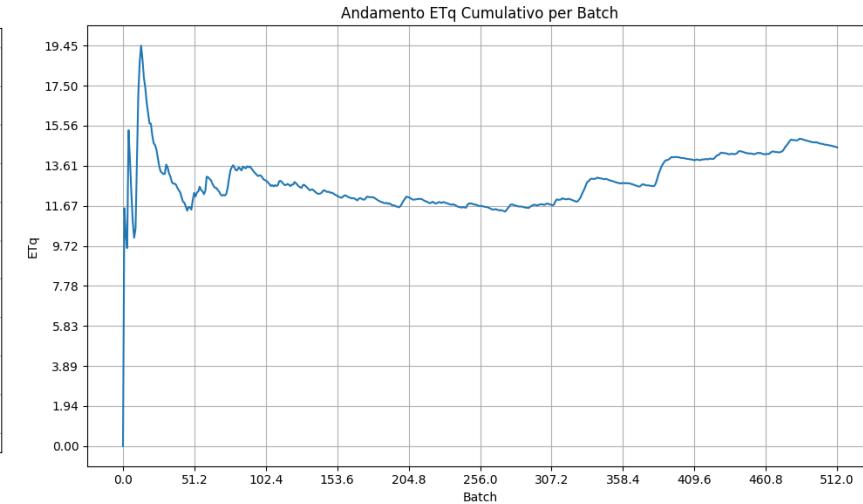
► Configurazione [24,4,12] 



CENTRO SMALL



CENTRO MEDIUM



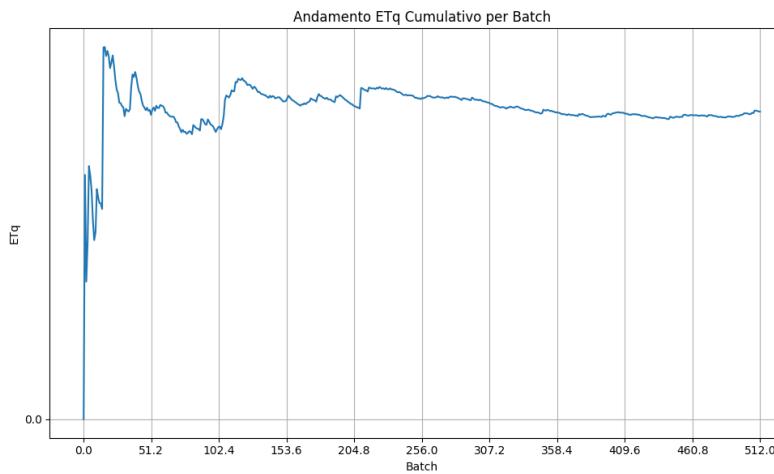
CENTRO LARGE

**High:**

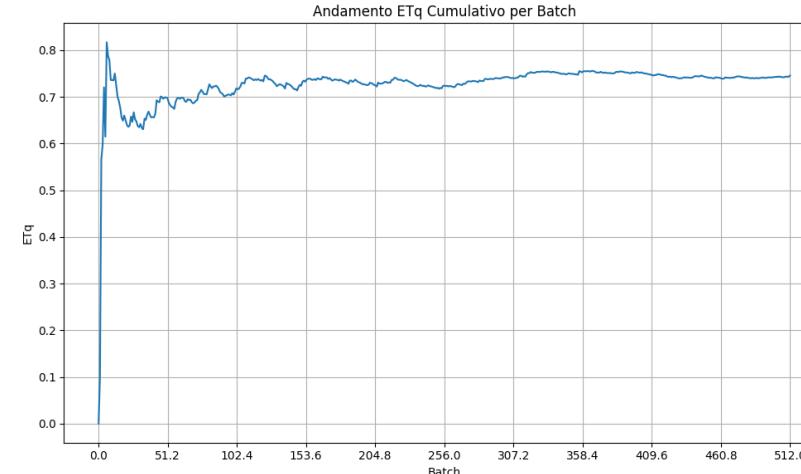
16 : 00 – 19 : 00

► Modello base:

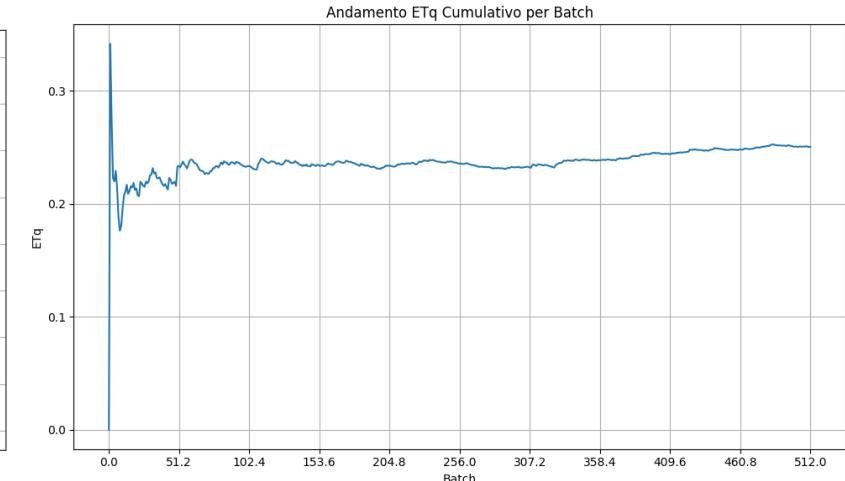
► Configurazione [33,6,16] ✓



CENTRO SMALL



CENTRO MEDIUM



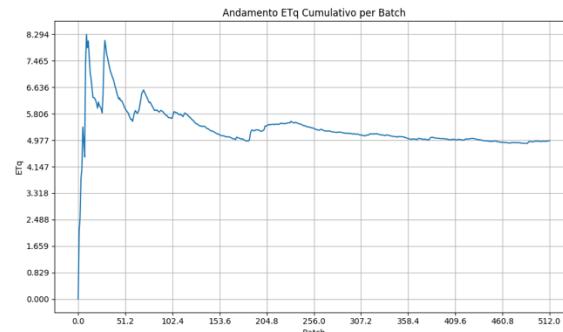
CENTRO LARGE

**High:**

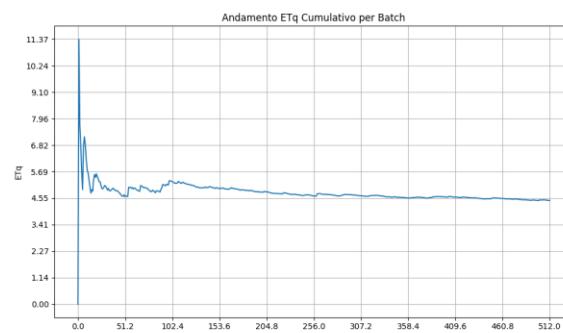
16 : 00 – 19 : 00

► **Modello migliorativo:**

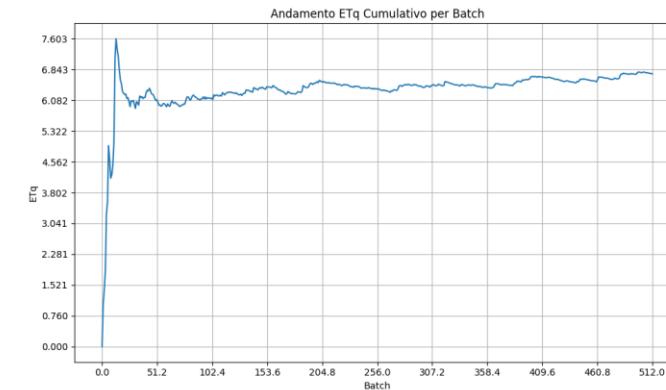
► Configurazione [18,4,9] [6,0,3] 



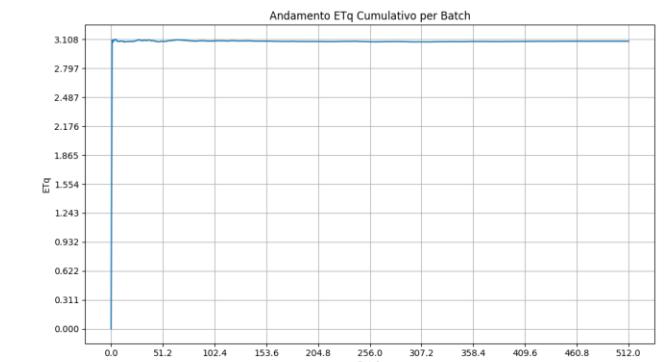
**CENTRO SMALL**



**CENTRO LARGE**



**CENTRO MEDIUM**



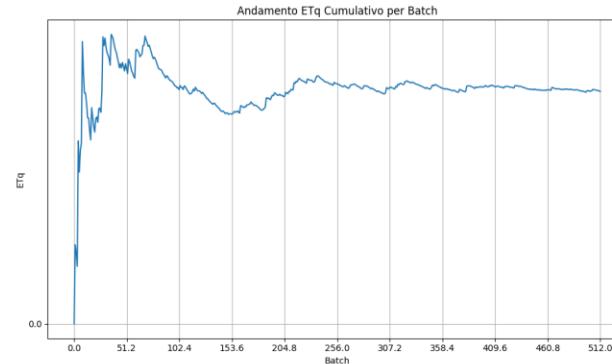
**CENTRO RIDE**

High:

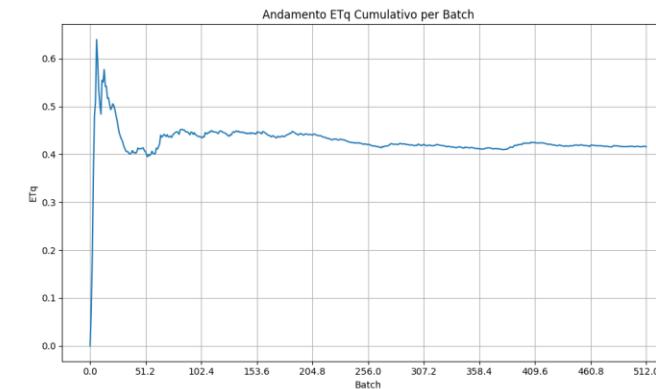
16 : 00 – 19 : 00

► Modello migliorativo:

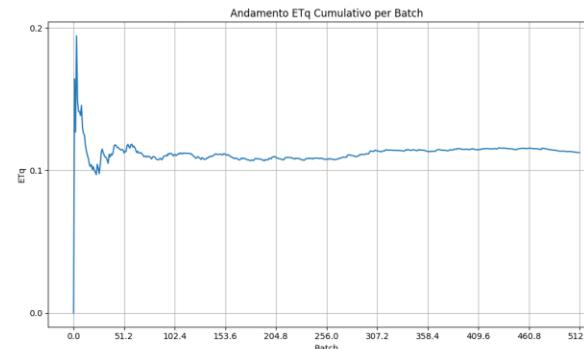
► Configurazione [27,6,13] [6,0,3] ✓



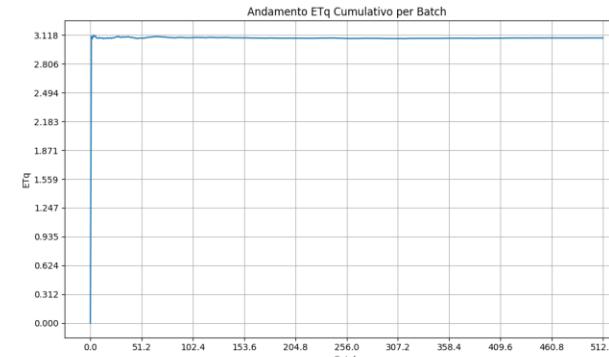
CENTRO SMALL



CENTRO MEDIUM



CENTRO LARGE



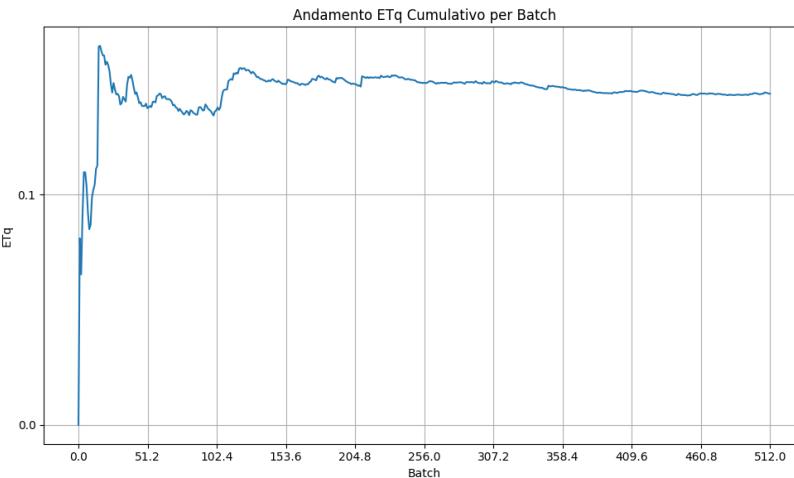
CENTRO RIDE

**Very High:**

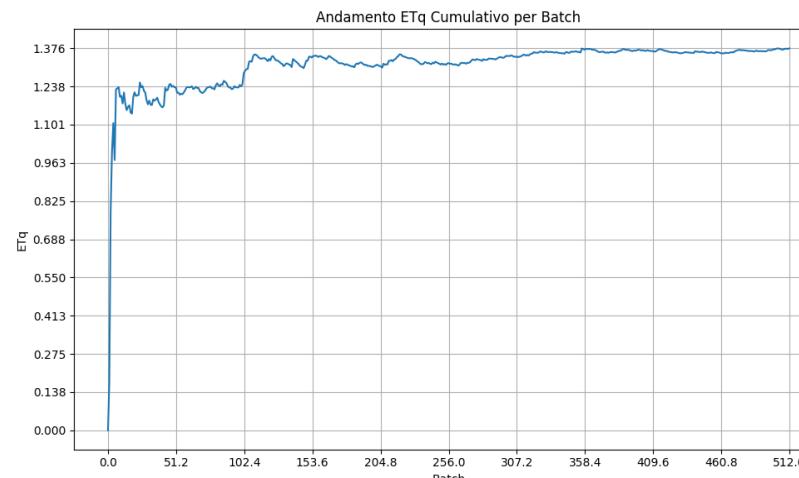
07 : 00 – 09 : 00

► **Modello base:**

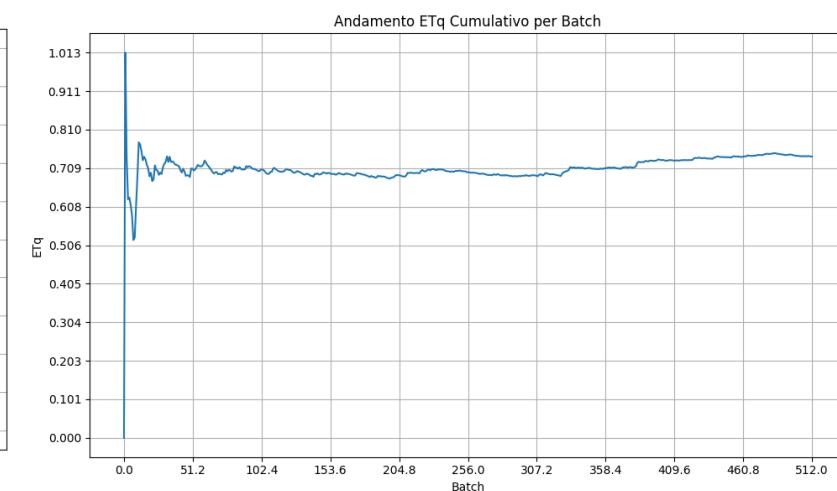
► **Configurazione [33,6,16]** ✓



**CENTRO SMALL**



**CENTRO MEDIUM**



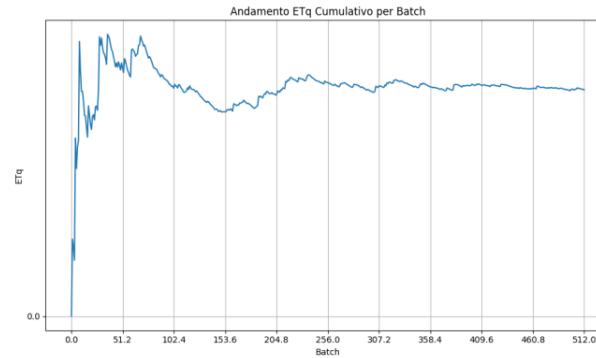
**CENTRO LARGE**

**Very High:**

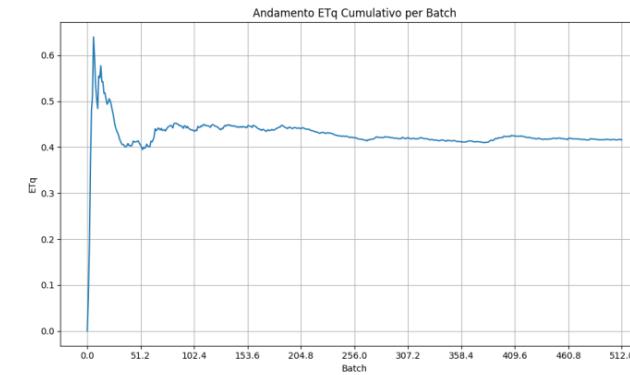
07 : 00 – 09 : 00

► **Modello migliorativo:**

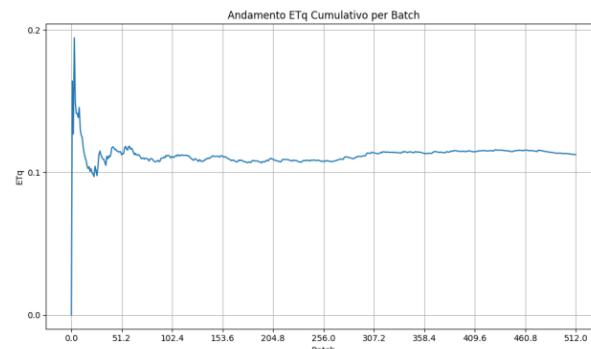
► Configurazione [27,6,13] [6,0,3] ✓



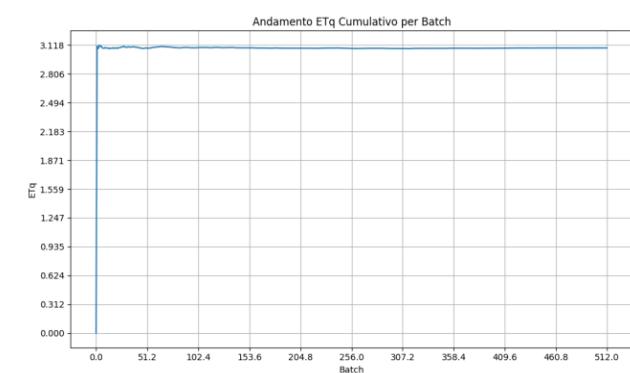
**CENTRO SMALL**



**CENTRO MEDIUM**



**CENTRO LARGE**



**CENTRO RIDE**

# Simulazione a orizzonte finito



- ▶ Studio esteso a tutto l'arco delle 24 ore (**1440 minuti**)
- ▶ Tasso di arrivo **variabile**: accensione e spegnimento dinamico dei server in base alla fascia oraria
- ▶ Verificare se le configurazioni ottimali identificate nel caso infinito sono in grado di sostenere i picchi di domande reali generati dal passaggio tra fasce a **bassa** e **alta** affluenza, garantendo i **vincoli di qualità del servizio**

# Gestione dei picchi reali

- Veicoli allocati per la fascia **very-low**: [6,2,3], [2,0,1]
- Veicoli allocati per la fascia **low**: [10,3,6], [5,0,2]
- Veicoli allocati per la fascia **medium**: [18,4,9], [6,0,3]
- Veicoli allocati per la fascia **high**: [27,6,13], [6,0,3]
- Veicoli allocati per la fascia **very-high**: [27,6,13], [6,0,3]

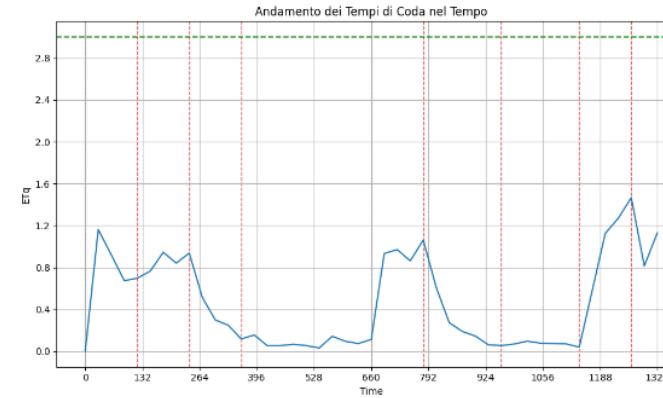


Figura 117: Centro small

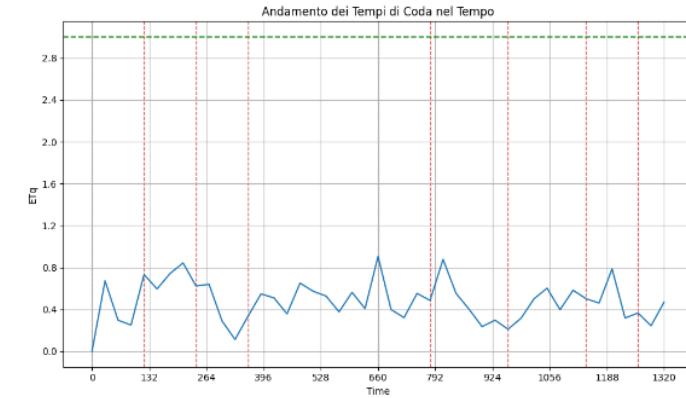


Figura 118: Centro medium

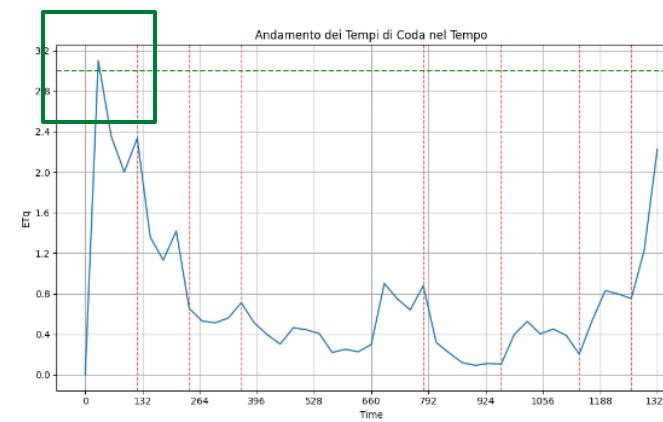


Figura 119: Centro large

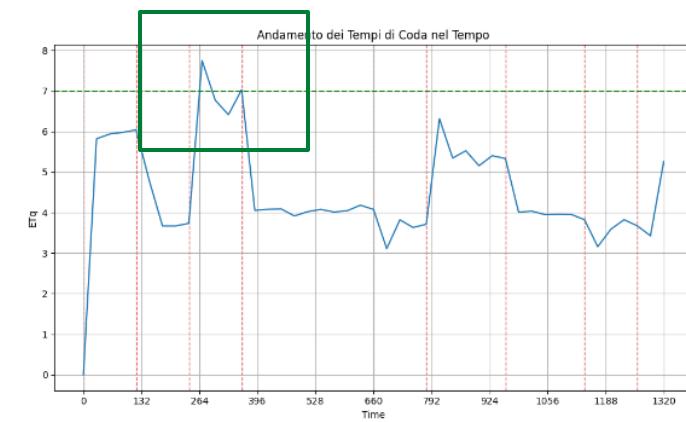


Figura 120: Centro ride-sharing

# Gestione dei picchi reali

- Veicoli allocati per la fascia **very-low**: [6,2,4], [2,0,1]
- Veicoli allocati per la fascia **low**: [10,3,6], [5,0,2]
- Veicoli allocati per la fascia **medium**: [18,4,9], [6,0,3]
- Veicoli allocati per la fascia **high**: [27,6,13], [6,0,3]
- Veicoli allocati per la fascia **very-high**: [27,6,12], [6,0,4]

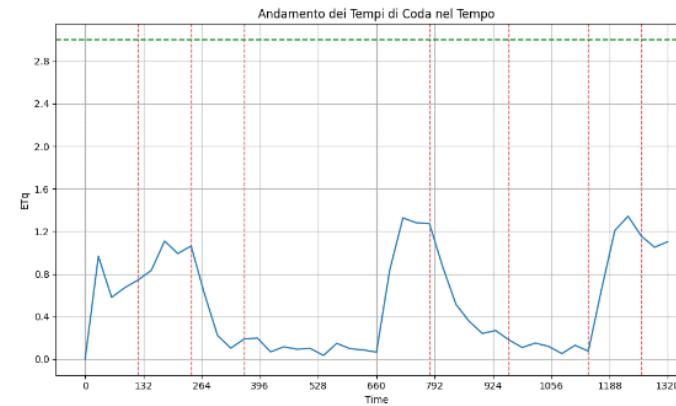


Figura 121: Centro small

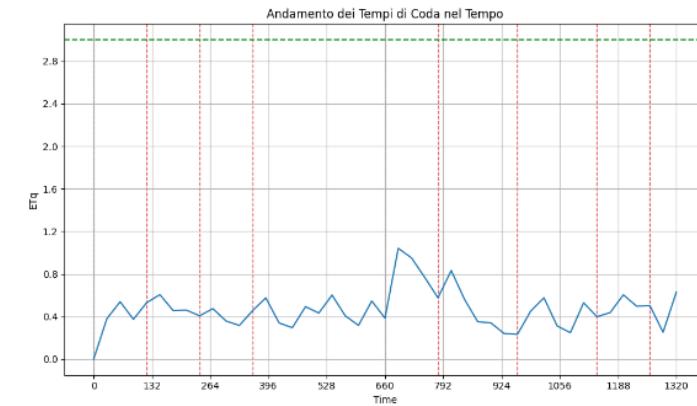


Figura 122: Centro medium

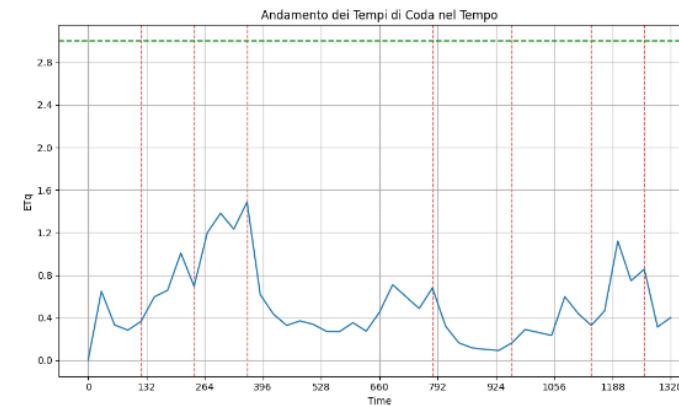


Figura 123: Centro large

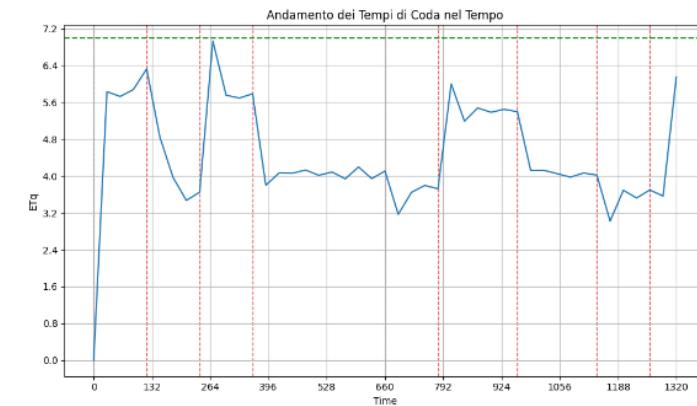


Figura 124: Centro ride-sharing

# Riduzione del numero totale dei veicoli

- Veicoli allocati per la fascia **very-low**: [6, 2, 3], [2, 0, 1]
- Veicoli allocati per la fascia **low**: [10, 3, 6], [5, 0, 2]
- Veicoli allocati per la fascia **medium**: [18, 4, 9], [6, 0, 3]
- Veicoli allocati per la fascia **high**: [23, 5, 11], [5, 0, 4]
- Veicoli allocati per la fascia **very-high**: [23, 5, 11], [5, 0, 4]

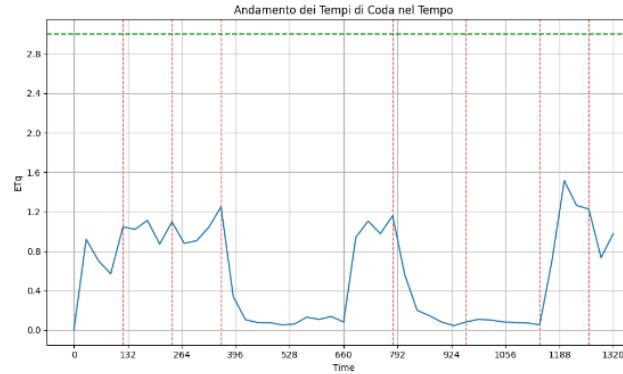


Figura 126: Centro small

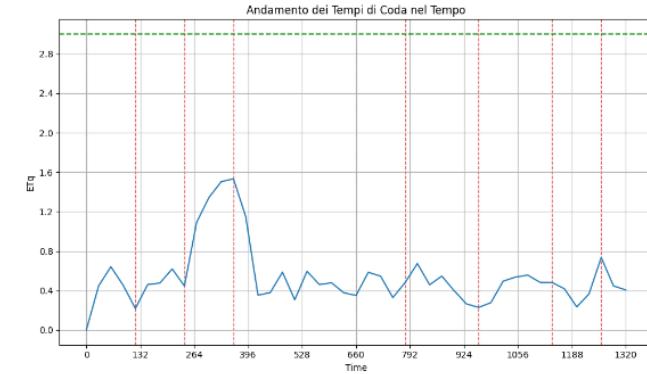


Figura 127: Centro medium

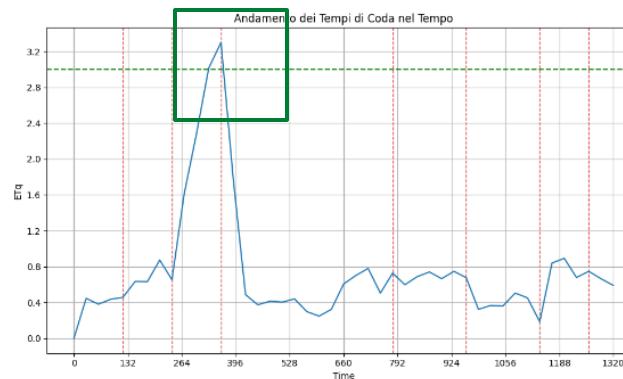


Figura 128: Centro large

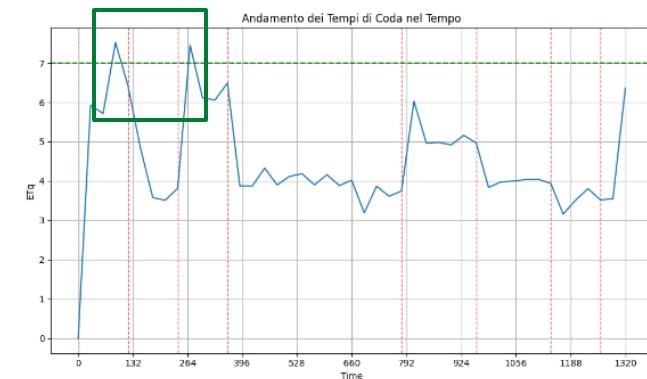


Figura 129: Centro ride-sharing

# Riduzione del numero totale dei veicoli

- Veicoli allocati per la fascia **very-low**: [6,2,3], [2,0,1]
- Veicoli allocati per la fascia **low**: [10,3,6], [5,0,2]
- Veicoli allocati per la fascia **medium**: [18,4,9], [6,0,3]
- Veicoli allocati per la fascia **high**: [23,5,11], [5,0,4]
- Veicoli allocati per la fascia **very-high**: [23,5,12], [5,0,5]

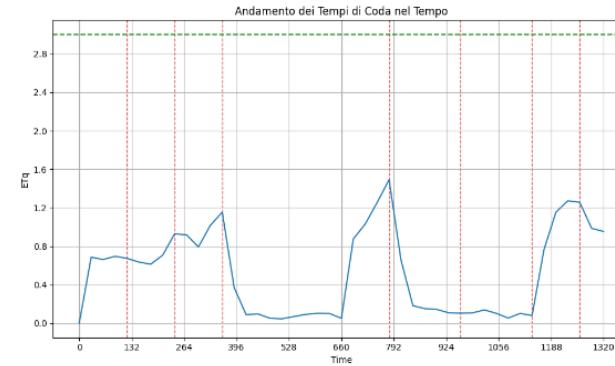


Figura 130: Centro small

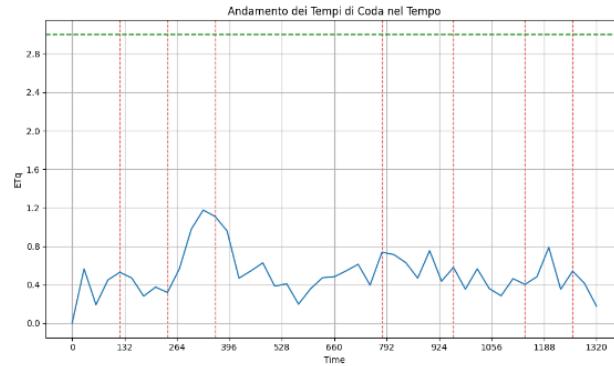


Figura 131: Centro medium

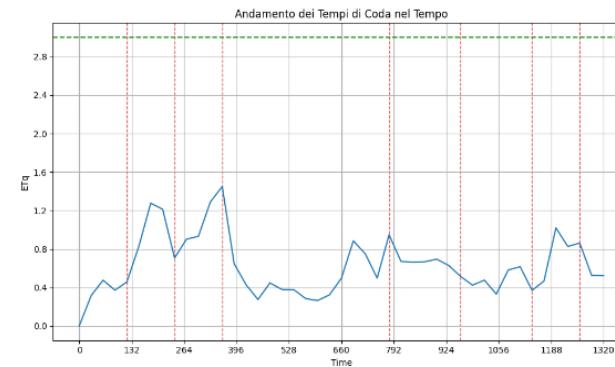


Figura 132: Centro large

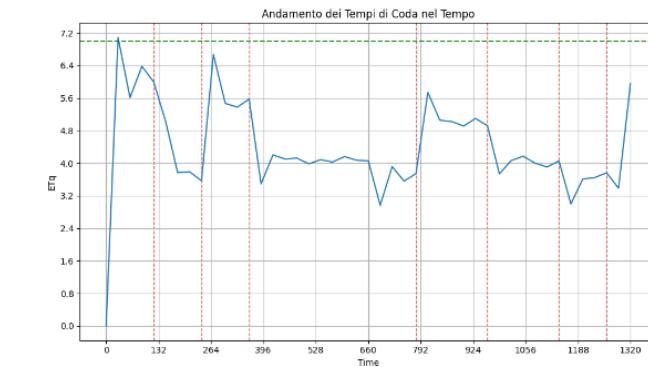


Figura 133: Centro ride-sharing

# Riduzione del numero totale dei veicoli

- Veicoli allocati per la fascia **very-low**: [6,2,3], [2,0,1]
- Veicoli allocati per la fascia **low**: [10, 3,6], [5,0,2]
- Veicoli allocati per la fascia **medium**: [15,4,8], [6,0,3]
- Veicoli allocati per la fascia **high**: [23,5,11], [5,0,4]
- Veicoli allocati per la fascia **very-high**: [23,5,12], [5,0,5]

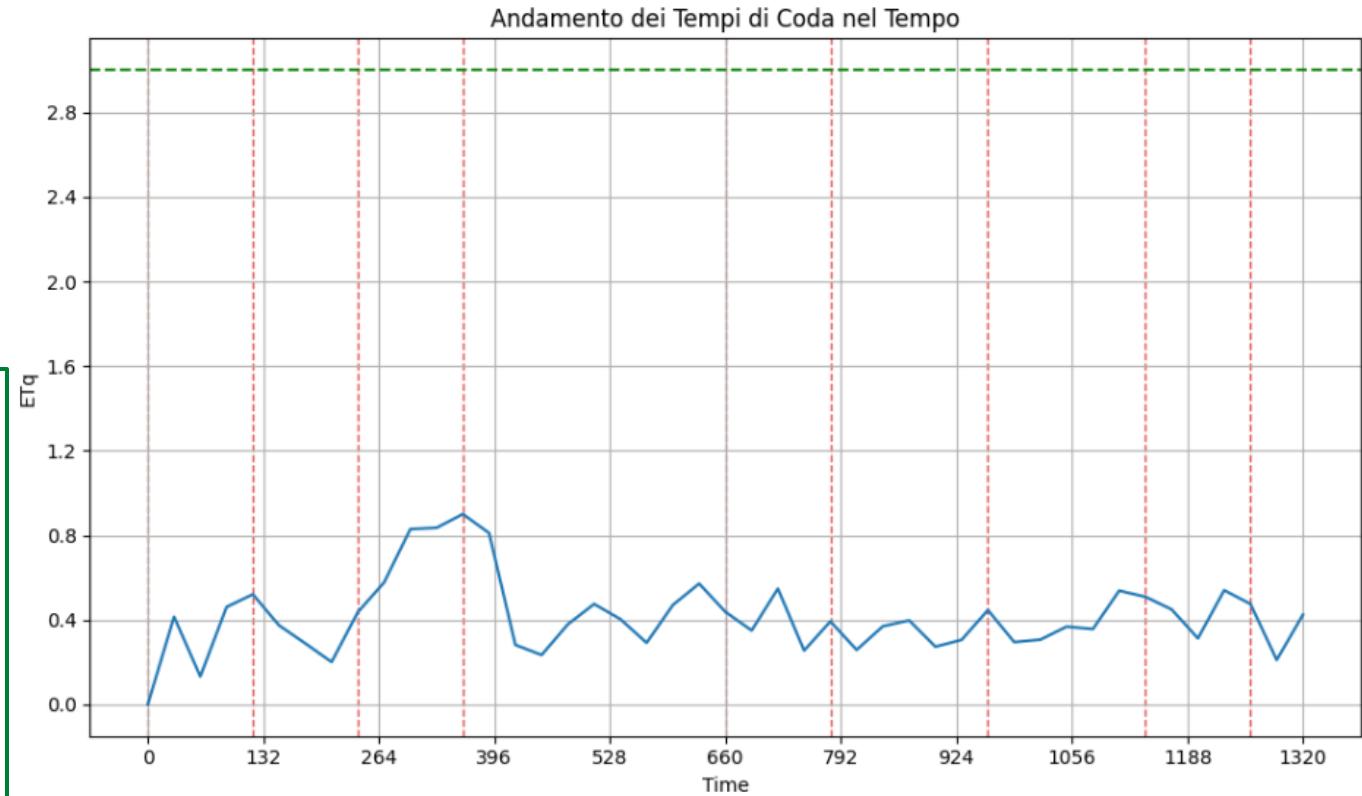


Figura 134: Centro medium



# Conclusioni

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- ▶ **Primo obiettivo:** ✓
  - ▶ Gestione dello stesso volume di richieste
  - ▶ Ridotta utilizzazione dei centri
  - ▶ Impatto poco significativo relativo ai *tempi di risposta*
- ▶ **Secondo obiettivo:** ✓
  - ▶ Riduzione del parco veicoli senza compromettere la qualità del servizio



TOR VERGATA  
UNIVERSITÀ DEGLI STUDI DI ROMA