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Métodos Determinísticos de Investigação Operacional - MDIO 2019/2020

### Mestrado Integrado em Engenharia Informática

# Trabalho 3

Grupo 25



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imagem com pessoa, homem, parede

Descrição gerada 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imagem com céu, pessoa, exterior, água

Descrição gerada automaticamente

![Uma imagem com pessoa, céu, homem, exterior

Descrição gerada automaticamente](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEASABIAAD/4S0KRXhpZgAATU0AKgAAAAgABwALAAIAAAAmAAAIbgESAAMAAAABAAEAAAExAAIAAAAmAAAIlAEyAAIAAAAUAAAIuodpAAQAAAABAAAIzoglAAQAAAABAAARUuocAAcAAAgMAAAAYgAAIXIc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAFdpbmRvd3MgUGhvdG8gRWRpdG9yIDEwLjAuMTAwMTEuMTYzODQAV2luZG93cyBQaG90byBFZGl0b3IgMTAuMC4xMDAxMS4xNjM4NAAyMDE3OjA5OjEzIDE2OjI2OjQyAAAGkAMAAgAAABQAABEokAQAAgAAABQAABE8kpEAAgAAAAQwOTYAkpIAAgAAAAQwOTYAoAEAAwAAAAEAAQAA6hwABwAACAwAAAkcAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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pDGSSJFGzyOERRksxwAK4zXPH9rZ7odNUXEoOPMb7g+nrWdWooLzOnD4d1ZeSPMda1W91edpb2d5SD8oJ4Uew6D8Ku2ThIkWvOm3JXZ2ySjKyNHh1qILz1xUpEsnjjGM5zV6P5UArSxmynqJxazN2CGuZtz94j/PSmb0NywrkVo2OsXuntutbmSLnOFbg/UdDQm4u6OxqM48sldHcaL47jmCw6mnlueBMg+U/UdvworthWi1qeRWwNSMvcV0dpmuc1vxjZ6Xuhgxc3A7KflU+5/oKqpNQV2ZYeg60+VHnur+IL/V3P2mclM5ES8KPwrCl6158pOTuz3OSNOHLHYryLvyPWtG1Be3UjrS6HJVWty9DLwAamIBPSkjJlmBecYq6FqzN7mDr11j/REPXmTH8qxIARuJPtig6aStYnzinK1I6kyRJeSKKClI/9n/4THoaHR0cDovL25zLmFkb2JlLmNvbS94YXAvMS4wLwA8P3hwYWNrZXQgYmVnaW49J++7vycgaWQ9J1c1TTBNcENlaGlIenJlU3pOVGN6a2M5ZCc/Pg0KPHg6eG1wbWV0YSB4bWxuczp4PSJhZG9iZTpuczptZXRhLyI+PHJkZjpSREYgeG1sbnM6cmRmPSJodHRwOi8vd3d3LnczLm9yZy8xOTk5LzAyLzIyLXJkZi1zeW50YXgtbnMjIj48cmRmOkRlc2NyaXB0aW9uIHJkZjphYm91dD0idXVpZDpmYWY1YmRkNS1iYTNkLTExZGEtYWQzMS1kMzNkNzUxODJmMWIiIHhtbG5zOnhtcD0iaHR0cDovL25zLmFkb2JlLmNvbS94YXAvMS4wLyI+PHhtcDpDcmVhdGVEYXRlPjIwMTctMDktMTNUMTY6MjY6MzIuMDk2PC94bXA6Q3JlYXRlRGF0ZT48eG1wOkNyZWF0b3JUb29sPldpbmRvd3MgUGhvdG8gRWRpdG9yIDEwLjAuMTAwMTEuMTYzODQ8L3htcDpDcmVhdG9yVG9vbD48L3JkZjpEZXNjcmlwdGlvbj48L3JkZjpSREY+PC94OnhtcG1ldGE+DQogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAg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imagem com pessoa, parede, homem, interior

Descrição gerada automaticamente](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEASABIAAD/4S1GRXhpZgAATU0AKgAAAAgABwALAAIAAAAmAAAIbgESAAMAAAABAAEAAAExAAIAAAAmAAAIlAEyAAIAAAAUAAAIuodpAAQAAAABAAAIzoglAAQAAAABAAARUuocAAcAAAgMAAAAYgAAIXIc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAFdpbmRvd3MgUGhvdG8gRWRpdG9yIDEwLjAuMTAwMTEuMTYzODQAV2luZG93cyBQaG90byBFZGl0b3IgMTAuMC4xMDAxMS4xNjM4NAAyMDE3OjA5OjExIDEwOjM3OjIzAAAGkAMAAgAAABQAABEokAQAAgAAABQAABE8kpEAAgAAAAQyMzcAkpIAAgAAAAQyMzcAoAEAAwAAAAEAAQAA6hwABwAACAwAAAkcAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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C5jY5yM4zyK0UkSRcowIqkIfmimBxX2h5pic8dqGz3AqBkbY3dvpTZER1KOoKt2piOO1jQijs6IWTr9Kx0N7aDEMzAL0BOf8ipsUmaw8S3VnHDHfQJcQTR87RjjoR71BJPo0s0ZtHuInbJaPHTGPX8fyqXHm3LjJx2NW2+wT4C3cig5AJHX36VrWEOnRXH2eMOwBAeVRwTjOCevT2xSjBRdxzqSkrM6CNg6hI12xL6DFSy3SwYUcueij+damIR/vFy3zE889alRpYeY5T16NzQBft9RDEJMNpPQ9jRTuBxjyeVbxzj0Ib8OR/WtJVDoJFOVYZGKQETx59eelV5VeNd2Mr3OaAGBkmXa3zetYl/pS7WKYBHOBQCM29sJpbe1KISVUg4+tQW+nol0xliywHAYdDk4NSiinFpQiwySSp/uEj+ddDYPcW9lNsO996HLjqOfSgZs2upXz/JtAzxwOlacDqvzON0hPzMepqkQy7HJngDj61IsnufwNMRJkbM8HPtiilYD/2QD/4THoaHR0cDovL25zLmFkb2JlLmNvbS94YXAvMS4wLwA8P3hwYWNrZXQgYmVnaW49J++7vycgaWQ9J1c1TTBNcENlaGlIenJlU3pOVGN6a2M5ZCc/Pg0KPHg6eG1wbWV0YSB4bWxuczp4PSJhZG9iZTpuczptZXRhLyI+PHJkZjpSREYgeG1sbnM6cmRmPSJodHRwOi8vd3d3LnczLm9yZy8xOTk5LzAyLzIyLXJkZi1zeW50YXgtbnMjIj48cmRmOkRlc2NyaXB0aW9uIHJkZjphYm91dD0idXVpZDpmYWY1YmRkNS1iYTNkLTExZGEtYWQzMS1kMzNkNzUxODJmMWIiIHhtbG5zOnhtcD0iaHR0cDovL25zLmFkb2JlLmNvbS94YXAvMS4wLyI+PHhtcDpDcmVhdGVEYXRlPjIwMTctMDktMTFUMTA6Mzc6MDkuMjM3PC94bXA6Q3JlYXRlRGF0ZT48eG1wOkNyZWF0b3JUb29sPldpbmRvd3MgUGhvdG8gRWRpdG9yIDEwLjAuMTAwMTEuMTYzODQ8L3htcDpDcmVhdG9yVG9vbD48L3JkZjpEZXNjcmlwdGlvbj48L3JkZjpSREY+PC94OnhtcG1ldGE+DQogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAKICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgIAogICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgCiAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAgICAg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# Introdução

Na unidade curricular Modelos Determinísticos de Investigação Operacional do 3ºano do Mestrado Integrados em Engenharia Informática, foi proposto um trabalho que foca no problema de encontrar caminhos críticos.

O trabalho 3 encontra-se dividido em três partes: Uma primeira onde ocorre uma apresentação do tema a ser abordado.

Na segunda parte é pedido para identificar 3 atividades que, no diagrama de Gantt da PARTE 0, decorrem em paralelo, bem como uma das atividades que seja selecionada deve pertencer ao caminho crítico. Após é restrito que atividades em paralelo, visto existir apenas um equipamento.

Já na terceira parte do trabalho é possível reduzir a duração de uma atividade aumentando os recursos e aplicando um custo adicional, num caso em que o custo da redução é não-linear.

# Parte 0

O maior número de inscrição é 85367, como indicado no enunciado serão removidos os vértices 6 e 7.  
Deste modo o vértice inicial conecta-se ao vértice 0,4,8,10.

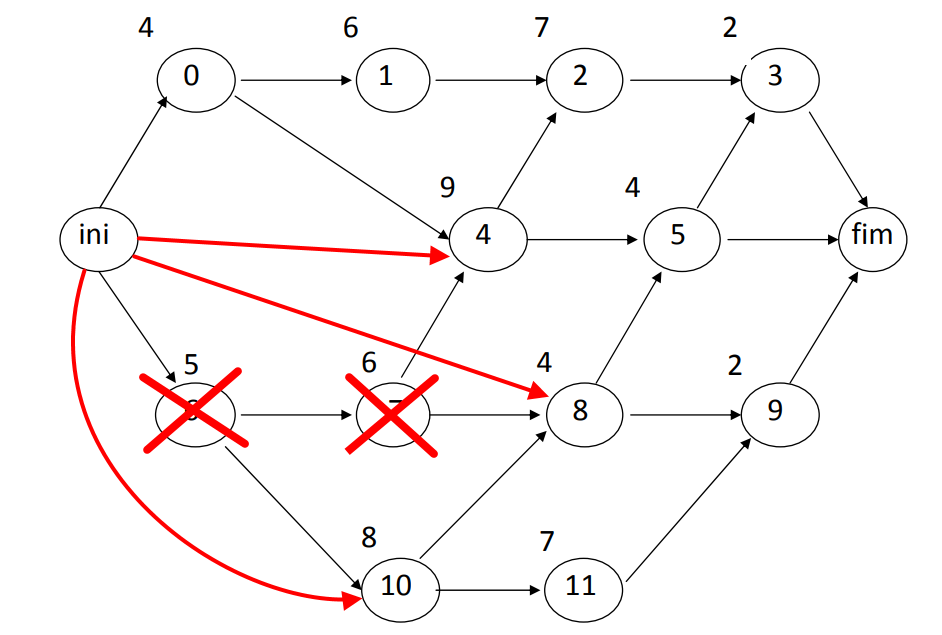


Figura 1: Rede do projeto depois de eliminar os respetivos vértices.

**Resolução do modelo com as variáveis de decisão ti ,∀i**

As restrições do problema, relativas a cada um dos arcos do grafo, traduzem as relações de precedência entre as atividades. Para uma dada atividade j, o tempo de início da atividade j deve ser superior ao tempo de conclusão de cada uma das atividades que precedem j. Dado que ti designa o tempo de início da atividade i, a função ti + di designa o tempo de conclusão da atividade i. O projeto termina no instante de tempo tf.

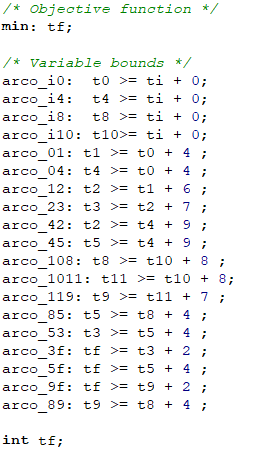


Figura 2: Modelo em LPSolve.

De seguida é apresentada a tabela, formulada pelo LPSolve, da qual irá resultar o diagrama de Gantt:

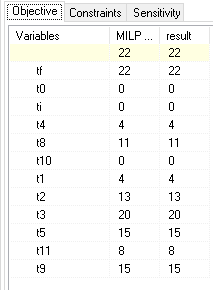


Figura 3: Output do modelo em LPSolve.

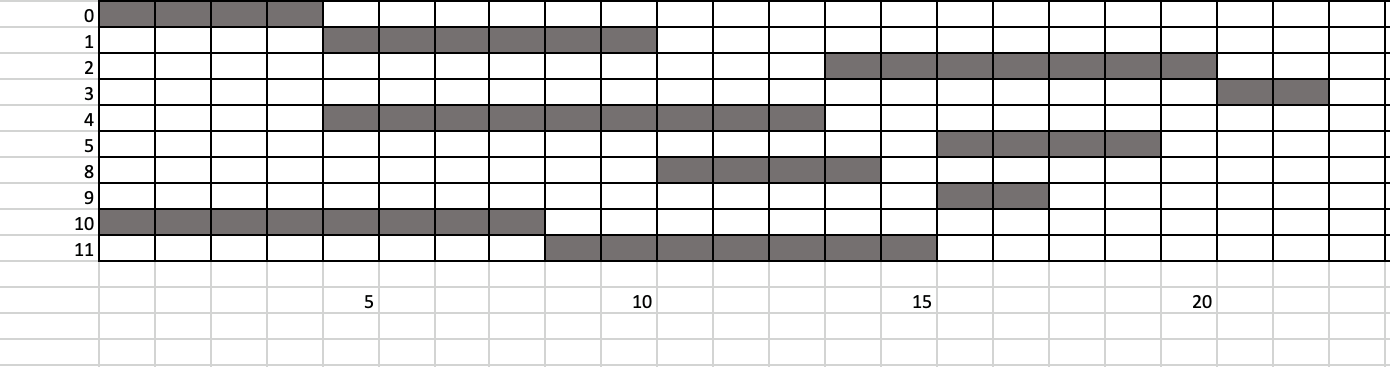


Figura 4: Diagrama de Gantt.

# Parte 1

Primeiramente, é pedida a seleção de 3 atividades que decorrem em paralelo no diagrama de Gantt. Decidimos selecionar as atividades 1,4 e 11. As atividades 1 e 4 têm prioridade relativamente à 11, visto começarem primeiro. Quando a atividade selecionada (1 ou 4) terminar, as que sobrarem (1 e 11 ou 4 e 11) têm igual prioridade.

Como há duas atividades que podem ser selecionadas inicialmente e duas a serem selecionadas quando a primeira atividade terminar, existem ao todo 4 combinações possíveis diferentes.

Nesta parte do trabalho o objetivo será a minimização do tempo final do caminho, como acontece na parte 0, deste modo a função objetivo será a mesma, porém apenas será disponível um recurso, desta forma não podem ocorrer atividades em paralelo.

Para que não ocorram atividades em paralelo vamos criar uma variávelbinaria **yij**, com valor 1 quando está em fila de espera, ou seja, a atividade i está à espera que a atividade j termine, e com valor 0 quando a atividade j está à espera que a atividade i termine.

Para que não ocorram ciclos é necessário implementar duas restrições:

nociclo: y(1,4)+ y(4,11) + y(11,1)<=2;

nociclo: y(1,4) + y(4,11) + y(11,1)>=1;

Como o LPSolve não permite utilizar parênteses, recorremos a restrições auxiliares de forma a conseguir a negação.

Nega1: y(1,11) = 1 - y(11,1);

Nega1: y(4,1) = 1 – y(1,4);

Nega1: y(11,4) = 1 - y(4,11);

Devido à partilha de recursos, as atividades selecionadas não podem correr em paralelo, como visto anteriormente. Por essa razão às restrições **ti>= tj + d** definidas na Parte 0vamos ter de adicionar restrições que vão fazer com que a atividade i espere que a outra atividade j que partilha os mesmos recursos termine.

Deste modo adicionamos um valor arbitrário às restrições da Parte 0 relativas às atividades com recursos partilhados, ficando as restrições:

* **ti + 118yji >= tj + d**, sendo que a atividade i espera que a atividade j acabe caso tenha que esperar por ela

Ficheiro Input

/\* Objective function \*/

min: tf;

/\* Variable bounds \*/

arco\_i0: t0 >= ti + 0;

arco\_i4: t4 >= ti + 0;

arco\_i8: t8 >= ti + 0;

arco\_i10: t10>= ti + 0;

arco\_01: t1 + 118\*y14 >= t4 + 9; //espera que a 4 termine caso tenha q esperar

arco\_01: t1 + 118\*y121 >= t12 + 7; //espera que a 12 termine caso tenha q esperar

arco\_01: t1 >= t0 + 4;

arco\_04: t4 >= t0 + 4;

arco\_04: t4 + 118\*y41 >= t1 + 6; //espera que a 1 termine caso tenha q esperar

arco\_04: t4 + 118\*y412 >= t12 + 7; //espera que a 12 termine caso tenha q esperar

arco\_12: t2 >= t1 + 6;

arco\_23: t3 >= t2 + 7;

arco\_42: t2 >= t4 + 9;

arco\_45: t5 >= t4 + 9;

arco\_108: t8 >= t10 + 8;

arco\_1011: t12 >= t10 + 8;

arco\_1011: t12 + 118\*y112>= t1 + 6; //espera que a 1 termine caso tenha q esperar

arco\_1011: t12 + 118\*y124>= t4 + 9; //espera que a 4 termine caso tenha q esperar

arco\_1011: t12 >= t10 + 8;

arco\_119: t9 >= t12 + 7;

arco\_85: t5 >= t8 + 4;

arco\_53: t3 >= t5 + 4;

arco\_3f: tf >= t3 + 2;

arco\_5f: tf >= t5 + 4;

arco\_9f: tf >= t9 + 2;

arco\_89: t9 >= t8 + 4;

no\_ciclo:y14+y412+y121<=2;

no\_ciclo:y14+y412+y121>=1;

nega1:y112=1-y121;

nega2:y41=1-y14;

nega3:y124=1-y412;

bin y14,y412,y121;

int tf,t1,t2,t3,t4,t5,t6,t7,t8,t9,t10,t12;

Ficheiro Output

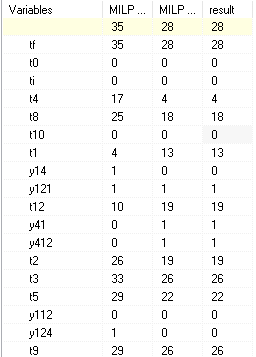


Figura 4: Output do modelo em LPSolve na Parte 1

Diagrama de Gantt

Uma imagem com shoji, edifício

Descrição gerada automaticamente

Figura 5: Diagrama de Gantt da Parte 1

Como podemos ver no diagrama as atividades 1, 4 e 11 já não correm em paralelo.

# Parte 2

Um modelo com funções não-lineares pode ser aproximado por um modelo em que cada uma dessas funções é aproximada por uma função contínua linear por partes. Nesta parte, para aproximar a função não-linear, vamos usar uma função linear com 2 partes.

Na variante em análise, cada atividade tem cinco parâmetros adicionais:

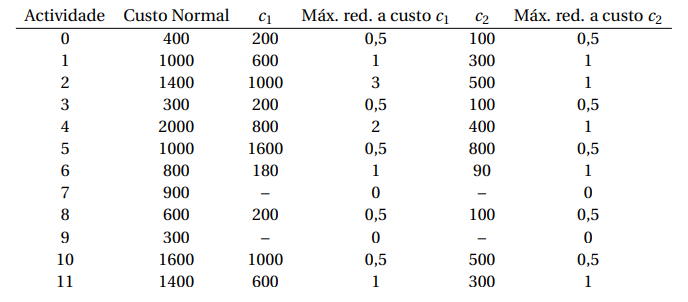


Figura 6: Tabela do enunciado

O objetivo é reduzir o tempo de execução calculado na Parte 0, ou seja, determinar a melhor forma de reduzir as durações de cada atividade com um tempo de execução de 19 U.T(no enunciado é nos pedido para reduzir, no mínimo, em 3 U.T, logo, 22-3=19).

A função objetivo seguinte tem como objetivo minimizar o valor dos custos suplementares de redução da duração das atividades. De forma a concretizar o pedido no enunciado do trabalho, acrescentamos restrições ao modelo utilizado na Parte 0 de forma a introduzir os custos suplementares **ct.** É necessário acrescentar variáveis que representem e guardem o valor de redução do custo do tempo da atividade **rdi**.

* **Função Objetivo**

A nossa função objetivo é *min: 200\*rd0ct1 + 100\*rd0ct2 + 600\*rd1ct1 +*

*300\*rd1ct2 + 1000\*rd2ct1 + 500\*rd2ct2 + 200\*rd3ct1 + 100\*rd3ct1 + 800\*rd4ct1 +*

*400\*rd4ct2 + 1600\*rd5ct1 + 800\*rd5ct2 + 180\*rd6ct1 + 90\*rd7ct2 + 200\*rd8ct1 + 100\*rd8ct2 + 1000\*rd10ct1 + 500\*rd10ct2 + 600\*rd11ct1 + 300\*rd11ct2.*

* **Restrições**

Sendo que o principal objetivo é reduzir o tempo de execução, a primeira

restrição a ser colocada é *tf<=19*.

­­Visto que o que se pretende reduzir o tempo das atividades, introduzimos

a cada arco do modelo a sua respetiva redução, ou seja a diferença do seu tempo de execução anterior e a redução precisa, **ex: arco\_01: t1>=t0+4-rd0ct1 – rd0ct2.**

***/\****

*arco\_i0 : t0 >= ti + 0;*

*arco\_i4 : t4 >= ti + 0;*

*arco\_i8 : t8 >= ti + 0;*

*arco\_i10 : t10 >= ti + 0;*

*arco\_01 : t1 >= t0 + 4 - rd0ct1 - rd0ct2;*

*arco\_04 : t4 >= t0 + 4 - rd0ct1 - rd0ct2;*

*arco\_12 : t2 >= t1 + 6 - rd1ct1 - rd1ct2;*

*arco\_23 : t3 >= t2 + 7 - rd2ct1 - rd2ct2;*

*arco\_42 : t2 >= t4 + 9 - rd4ct1 - rd4ct2;*

*arco\_45 : t5 >= t4 + 9 - rd4ct1 - rd4ct2;*

*arco\_108 : t8 >= t10 + 8 - rd10ct1 - rd10ct2;*

*arco\_1011: t11 >= t10 + 8 - rd10ct1 - rd10ct2;*

*arco\_119 : t9 >= t11 + 7 - rd11ct1 - rd11ct2;*

*arco\_85 : t5 >= t8 + 4 - rd8ct1 - rd8ct2;*

*arco\_53 : t3 >= t5 + 4 - rd5ct1 - rd5ct2;*

*arco\_3f : tf >= t3 + 2 - rd3ct1 - rd3ct2;*

*arco\_5f : tf >= t5 + 4 - rd5ct1 - rd5ct2;*

*arco\_9f : tf >= t9 + 2;*

*arco\_89 : t9 >= t8 + 4 - rd8ct1 - rd8ct2;*

*\*/*

**Nota:** Como não temos a atividade 6 e 7 as variáveis rd6ct1, rd6ct2, rd7ct1 e rd7ct2 não existem.

Como só é permitido utilizar **rdct2** quando o **rdct1** atingiu o limite é necessário adicionar restrições de forma a que o mesmo se verifique, **ex: 1000y0 >= 0.5 - rd0ct1**.

*/\**

*1000 y0 >= 0.5 - rd0ct1;*

*1000 y1 >= 1 - rd1ct1;*

*1000 y2 >= 3 - rd2ct1;*

*1000 y3 >= 0.5 - rd3ct1;*

*1000 y4 >= 2 - rd4ct1;*

*1000 y5 >= 0.5 - rd5ct1;*

*1000 y8 >= 0.5 - rd8ct1;*

*1000 y10 >= 0.5 - rd10ct1;*

*1000 y11 >= 1 - rd11ct1;*

*\*/*

Esta variável **yi**(atividade i) binária surge de uma necessidade de confirmar se o valor máximo de **rdict1** já foi atingindo. Quando **yi**=0 significa que o valor máximo de **rdict1** já foi atingido, caso o valor de **yi** seja 1 o valor máximo ainda não foi atingido e, por isso, **rdict2** ainda não pode ser utilizado.

Como no LPSolve não se pode utilizar parêntesis utilizamos novas variáveis, **xi**, para fazer a negação do **yi**, **ex: x0= 1 – y0**.

*/\**

*x0 = 1 - y0;*

*x1 = 1 - y1;*

*x2 = 1 - y2;*

*x3 = 1 - y3;*

*x4 = 1 - y4;*

*x5 = 1 - y5;*

*x8 = 1 - y8;*

*x10 = 1 - y10;*

*x11 = 1 - y11;*

*\*/*

Também é necessário incluir no modelo as restrições presentes na tabela referentes ao tempo máximo de redução.

*/\**

*rd0ct1 <= 0.5 ;*

*rd0ct2 <= 0.5\*x0;*

*rd1ct1 <= 1 ;*

*rd1ct2 <= 1\*x1;*

*rd2ct1 <= 3 ;*

*rd2ct2 <= 1\*x2;*

*rd3ct1 <= 0.5;*

*rd3ct2 <= 0.5\*x3;*

*rd4ct1 <= 2;*

*rd4ct2 <= 1\*x4;*

*rd5ct1 <= 0.5;*

*rd5ct2 <= 0.5\*x5;*

*rd8ct1 <= 0.5;*

*rd8ct2 <= 0.5\*x8;*

*rd10ct1 <= 0.5;*

*rd10ct2 <= 0.5\*x10;*

*rd11ct1 <= 0.5;*

*rd11ct2 <= 0.5\*x11;*

*\*/*

*Uma imagem com captura de ecrã

Descrição gerada automaticamente*

Figura 7: Input LPSolve Parte 2

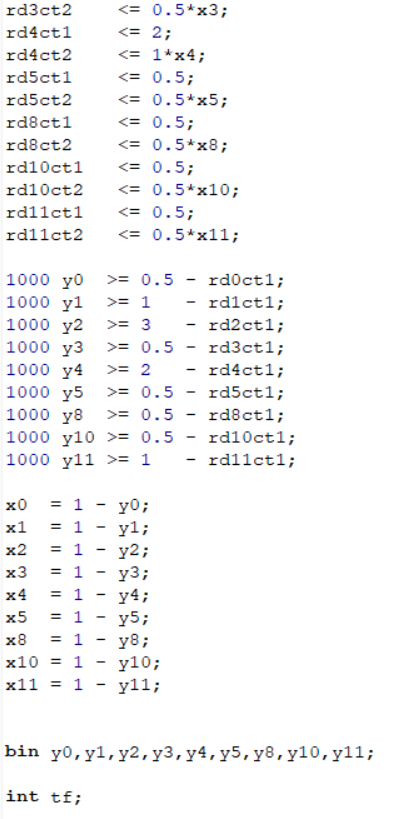


Figura 8: Continuação Input LPSolve Parte 2

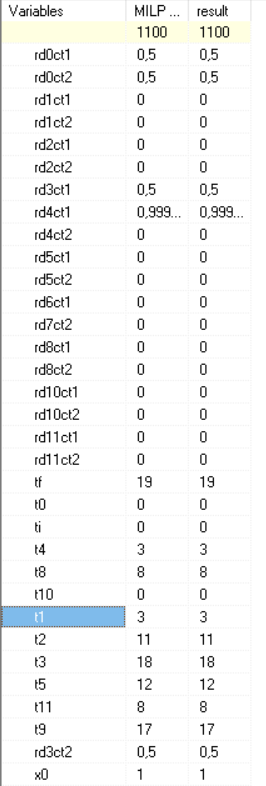


Figura 9: Output LPSolve Parte 2

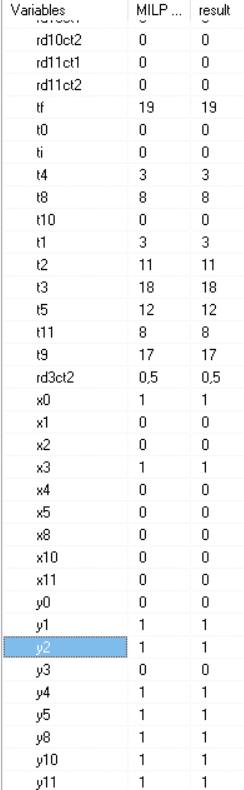


Figura 10: Output LPSolve Parte 2

Uma imagem com shoji, edifício, palavras cruzadas, jogador

Descrição gerada automaticamente

Figura 11: Diagrama de Gantt da Parte 2

A atividade 0 ficou com a duração reduzida em 1 U.T..

A atividade 3 ficou com duração reduzida em 1 U.T..

A atividade 4 ficou com duração reduzida em 1 U.T..

O custo desta redução temporal nas atividades é de 1100.Como se pode

visualizar na imagem do output os valores de rd0ct1, rd0ct2, rd3ct1, rd3ct2, rd4ct1 tem o valor de 0.5, 0.5,0.5, 0.5, 1 respetivamente.

**Verificação do custo da solução:**

200 \*rd0ct1 + 100 \* rd0ct2 + 200 \* rd3ct1 + 100\*rd3ct2 + 800\*rd4ct1 = 1100.