**ŽILINSKÁ UNIVERZITA V ŽILINE**

FAKULTA RIADENIA A INFORMATIKY

Semestrálna práca

Simulácia stanice STK

Agentovo orientovaná simulácia

ŠTUDIJNÝ ODBOR: INFORMAČNÉ SYSTÉMY

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5ZIS12

Žilinská univerzita v Žiline

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Žilina, 2023

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# Programátorská časť

**Model prevádzky STK**

Obrázok, na ktorom je diagram

Automaticky generovaný popisModel obsahuje 5 agentov ktorý spolu navzájom komunikujú.

**Agent okolia - AgentSurroundings**

**Obrázok, na ktorom je text, snímka obrazovky, diagram, dizajn

Automaticky generovaný popis**

Agent okolia má na starosti príchody zákazníkov do prevádzky STK. Funguje tak, že na začiatku replikácie sa pošle inicializačná správa, že má plánovač príchodov zákazníkov (SchedulerCustomerArrival) začať plánovať príchody. Po príchode zákazníka si plánovač pošle sám sebe správu, oneskorenú o vygenerovaný čas príchodu ďalšieho zákazníka a druhú správu, ktorá obsahuje oboznámi agenta modelu že prišiel zákazník do prevádzky. Taktiež agent okolia prijíma správy o odchode zákazníkov z prevádzky, ktoré spracuje tak, že aktualizuje štatistiky týkajúce sa zákazníkov v prevádzke.

**Agent modelu - AgentModel**

**Obrázok, na ktorom je text, kruh, kompaktný disk, písmo

Automaticky generovaný popis**

Agent modelu má na starosti posielanie správ medzi agentom okolia a agentom STK. Agentovi STK posiela správy o príchode zákazníkov a agentovi okolia o ich odchode.

**Agent STK – AgentSTK**

**Obrázok, na ktorom je kruh, text, kompaktný disk, zariadenie na ukladanie údajov

Automaticky generovaný popis**

Agent STK má na starosti posielanie správ medzi agentami modelu, recepcie a dielne. Správy posielané agentovi recepcie sú o príchode zákazníka, informácia či sú voľné zdroje v dielni na vykonanie inšpekcie (mechanik/parkovacie miesto), informácia o ukončení inšpekcie a informácia o uvoľnení zdroja po obednej prestávke.  
Agentovi dielne posiela správy informujúce o dostupnosti zdrojov pre inšpekciu zákazníka a začiatku inšpekcie zákazníka.

**Agent recepcia - AgentReception** **Obrázok, na ktorom je kruh, text, diagram, snímka obrazovky

Automaticky generovaný popis**

Agent recepcie má na starosti prijatie zákazníka do prevádzky, vykonanie platby za inšpekciu a vykonanie obednej prestávky pre prijímacích technikov. Tento agent pracuje takým spôsobom, že najskôr zareaguje na prijatú správu o tom, že zákazník prišiel do recepcie. Na ňu reaguje tak, že pošle správu, v ktorej žiada priradenie voľného zdroja z dielne, keď príde odpoveď na túto správu, tak zákazníka buď postaví do fronty na prevzatie auta ak nie sú voľné zdroje, alebo ho pošle na prevzatie auta. Po prevzatí auta pošle zákazníka na inšpekciu a pozrie sa či niekto čaká buď vo fronte na platbu, alebo vo fronte na prevzatie auta, ak niekto čaká, tak sa vykoná daný proces. Keď príde správa o vykonaní inšpekcie, tak sa zákazník buď postaví do frontu zákazníkov čakajúcich na platbu, alebo ak je voľný pokladník, tak sa začne vykonávať platba. Po ukončení platby sa zákazník pošle von z prevádzky.

Obedná prestávka sa vykoná tak, že o 11tej sa pošlú voľný pracovníci na obed, tak, aby niekto ostal na pokladni, a tí ktorý robia, po skončení práce, ak sa niekto už vrátil z obeda, pôjdu tiež na prestávku, ak sa nikto nevrátil z obeda robia kým nebude 12:15, po tomto čase sa pošlú na obed po skončení aktuálnej práce.

**Agent dielne - AgentWorkshop**

Obrázok, na ktorom je text, kruh, snímka obrazovky, diagram

Automaticky generovaný popis

Agent dielne má na starosti vykonanie inšpekcie. Tento agent pracuje takým spôsobom, že najskôr príjme správu, ktorá žiada o pridelenie zdrojov. Následne sa pošle informácia do agenta recepcie o tom, aký zdroj bol pridelený, ak nebol pridelený žiadny, sa zákazník postaví do radu na prevzatie auta. Ďalej agent dielne reaguje na správu o začatí inšpekcie a to tak, že skontroluje pridelený zdroj a ak je pridelený mechanik, pošle sa na inšpekciu a ak je zákazníkovi pridelené miesto na parkovisku, tak sa skontroluje či sa medzičasom neuvoľnil mechanik, ak áno, tak sa pošle na inšpekciu spolu s prideleným mechanikom, inak ostane na parkovisku, kým sa neuvoľní mechanik.

Keďže nákladné autá môžu kontrolovať iba pracovníci s certifikátom typu 2, budú uprednostňovať tieto autá pri výbere auta z parkoviska. Ak nebude na parkovisku nákladné auto, tak mechanik s certifikátom typu 2 zoberie auto ktoré je na rade.

Obedná prestávka sa vykoná tak, že o 11tej sa pošlú všetci pracovníci čo nerobia na obed a každý pracovník čo dorobí sa pošle na obed.

**Správa – MyMessage**

Správa, ktorá sa posiela medzi agentami obsahuje informácie o zákazníkovi, pokladníkovi, mechanikovi, o type auta a aký zdroj bol priradený zákazníkovy.

## Zmeny v 2.SP

V 2.SP sa oproti verzií ktorá bola odovzdaná zmenilo iba počítanie štatistiky pre počet voľných pokladníkov v udalosti CustomerArrival a to tak, že sa posielala na počítanie zlá hodnota počtu voľných pokladníkov, táto chyba bola opravená a už sa posiela správna hodnota na výpočet štatistiky.

## Validácia

Na validáciu agentovo orientovanej simulácie sa použije udalostná simulácia. Validácia sa vykoná na 40000 replikáciach s nasledujúcimi kombináciami príjmacích technikov a mechanikov: 1/1, 10/10, 50/50 a 4/17.

**Kombinácia 1/1**

|  |  |  |  |
| --- | --- | --- | --- |
| 1/1 | | | |
| Štatistika | Priemer 2.SP | Priemer 3.SP | Rozdiel |
| Customers arrived | 156,20263 | 156,220675 | -0,018045 |
| Customers in system | 85,49823 | 85,5101968 | -0,011966801 |
| Customers in system at the end | 145,03128 | 145,042 | -0,01072 |
| Customers in check in queue | 79,7281 | 79,74049182 | -0,012391824 |
| Time in system | 241,38261 | 241,267005 | 0,115605024 |
| Time in check in queue | 151,00402 | 150,9241293 | 0,07989072 |
| Time in payment in queue | 0,08759 | 0,086231059 | 0,001358941 |
| Free clerks | 0,69491 | 0,694697349 | 0,000212651 |
| Free mechanics | 0,01508 | 0,01511189 | -3,18902E-05 |
| Time in system 90% CI | 241,08351 | 241,68171 | 241,18879 | 241,34522 |  |
| Customers in system 95%CI | 85,42163 | 85,57482 | 85,43381 |  85,58658 |  |

**Kombinácia 10/10**

|  |  |  |  |
| --- | --- | --- | --- |
| 10/10 | | | |
| Štatistika | 2.SP | 3.SP | Rozdiel |
| Customers arrived | 156,17365 | 156,1472 | 0,02645 |
| Customers in system | 41,11762 | 41,09406037 | 0,02355963 |
| Customers in system at the end | 47,65478 | 47,64265 | 0,01213 |
| Customers in check in queue | 26,26904 | 26,24581864 | 0,023221357 |
| Time in system | 120,33766 | 120,2685799 | 0,069080094 |
| Time in check in queue | 70,08411 | 69,99909452 | 0,08501548 |
| Time in payment in queue | 7,00E-05 | 6,83E-05 | 1,69857E-06 |
| Free clerks | 7,68301 | 7,683000814 | 9,18594E-06 |
| Free mechanics | 0,42354 | 0,423638569 | -9,85685E-05 |
| Time in system 90% CI | 120,29916 | 120,37616 | 120,14949 | 120,38767 |  |
| Customers in system 95%CI | 41,04386 | 41,19138 | 41,0201 | 41,16802 |  |

**Kombinácia 50/50**

|  |  |  |  |
| --- | --- | --- | --- |
| 50/50 | | | |
| Štatistika | Priemer 2.SP | Priemer 3.SP | Rozdiel |
| Customers arrived | 156,35615 | 156,3027 | 0,05345 |
| Customers in system | 16,1665 | 16,16236392 | 0,004136076 |
| Customers in system at the end | 0,00018 | 5,00E-05 | 0,00013 |
| Customers in check in queue | 0 | 0 | 0 |
| Time in system | 49,62975 | 49,63433343 | -0,004583432 |
| Time in check in queue | 0 | 0 | 0 |
| Time in payment in queue | 0 | 0 | 0 |
| Free clerks | 46,97931 | 46,98069165 | -0,001381649 |
| Free mechanics | 36,85419 | 36,85694443 | -0,002754427 |
| Time in system 90% CI | 49,62564 | 49,63385 | 49,63022 | 49,63845 |  |
| Customers in system 95%CI | 16,15381 | 16,1792 | 16,14963 | 16,1751 |  |

**Kombinácia 4/17**

|  |  |  |  |
| --- | --- | --- | --- |
| 4/17 | | | |
| Štatistika | Priemer 2.SP | Priemer 3.SP | Rozdiel |
| Customers arrived | 156,27998 | 156,1485 | 0,13148 |
| Customers in system | 19,19406 | 19,1645621 | 0,029497905 |
| Customers in system at the end | 0,77962 | 0,77515 | 0,00447 |
| Customers in check in queue | 2,41334 | 2,401800428 | 0,011539572 |
| Time in system | 58,81703 | 58,44999081 | 0,367039189 |
| Time in check in queue | 7,41036 | 7,023732649 | 0,386627351 |
| Time in payment in queue | 0,77483 | 0,767033984 | 0,007796016 |
| Free clerks | 0,98453 | 0,986287385 | -0,001757385 |
| Free mechanics | 3,87302 | 3,88613815 | -0,01311815 |
| Time in system 90% CI | 58,8091 | 58,82496 | 58,39884 | 58,50114 |  |
| Customers in system 95%CI | 19,15973 | 19,22838 | 19,1303 | 19,19883 |  |

## Výsledky validácie

Z výsledkov validačných experimentov môžeme vidieť, že štatistiky aj intervaly spoľahlivosti sa mierne líšia, ale stále sa prekrývajú. Toto môže byť spôsobené použitím rozdielnych jadier simulácie ako aj využitím iných metód na zber a výpočet štatistík.

# Simulačná štúdia

## Experimenty – normálny vstupný tok

**Kombinácia 100/100/100**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 156,2537 | 156,1235 | 156,3839 | 156,0986 | 156,4089 |
| Customers departed | 156,2534 | 156,1232 | 156,3836 | 156,0982 | 156,4085 |
| Customers in system | 16,90853 | 16,89425 | 16,9228 | 16,89152 | 16,92553 |
| Time in system | 51,94234 | 51,93483 | 51,94985 | 51,93339 | 51,95128 |
| Customers in system at the end | 0,00036 | 0,00016 | 0,00056 | 0,00012 | 0,0006 |
| Customers in check in queue | 0,384803 | 0,38333 | 0,38627 | 0,38305 | 0,38656 |
| Time in check in queue | 1,182119 | 1,17769 | 1,18654 | 1,17685 | 1,18739 |
| Customers in payment queue | 0,358685 | 0,35742 | 0,35995 | 0,35717 | 0,3602 |
| Time in payment in queue | 1,102054 | 1,09825 | 1,10586 | 1,09752 | 1,10659 |
| Customers in parking lot | 0,025712 | 0,02498 | 0,02644 | 0,02484 | 0,02658 |
| Time in parking lot | 0,025394 | 0,02467 | 0,02612 | 0,02453 | 0,02626 |
| Free clerks | 90,73064 | 90,72807 | 90,73321 | 90,72758 | 90,7337 |
| Free mechanics group 1 | 82,86998 | 82,86013 | 82,87983 | 82,85825 | 82,88172 |
| Free mechanics group 2 | 91,49149 | 91,48645 | 91,49652 | 91,48549 | 91,49749 |
| Labour costs | 460000 |  |  |  |  |
| Number of replications | 25000 |  |  |  |  |

**Kombinácia 4/12/7**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 156,28298 | 156,19114 | 156,37482 | 156,17355 | 156,39241 |
| Customers departed | 154,54042 | 154,46444 | 154,6164 | 154,44989 | 154,63095 |
| Customers in system | 22,54116541 | 22,50526 | 22,57707 | 22,49838 | 22,58395 |
| Time in system | 68,54857093 | 68,47573 | 68,62141 | 68,46178 | 68,63536 |
| Customers in system at the end | 1,74256 | 1,71321 | 1,77191 | 1,70759 | 1,77753 |
| Customers in check in queue | 5,624298308 | 5,59696 | 5,65163 | 5,59173 | 5,65687 |
| Time in check in queue | 16,65521297 | 16,58267 | 16,72776 | 16,56878 | 16,74165 |
| Customers in payment queue | 0,393663645 | 0,393 | 0,39433 | 0,39287 | 0,39445 |
| Time in payment in queue | 1,212310399 | 1,21062 | 1,214 | 1,2103 | 1,21432 |
| Customers in parking lot | 0,489385224 | 0,48804 | 0,49073 | 0,48778 | 0,49099 |
| Time in parking lot | 1,252981462 | 1,2496 | 1,25637 | 1,24895 | 1,25702 |
| Free clerks | 0,738314515 | 0,73659 | 0,74004 | 0,73626 | 0,74037 |
| Free mechanics group 1 | 2,860032443 | 2,8559 | 2,86416 | 2,85511 | 2,86495 |
| Free mechanics group 2 | 1,853444763 | 1,84999 | 1,8569 | 1,84932 | 1,85757 |
| Labour costs | 36400 |  |  |  |  |
| Number of replications | 50000 |  |  |  |  |

**Kombinácia 5/11/7**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 156,25966 | 156,16811 | 156,35121 | 156,15058 | 156,36874 |
| Customers departed | 155,15992 | 155,07949 | 155,24035 | 155,06408 | 155,25576 |
| Customers in system | 21,42697741 | 21,39309 | 21,46086 | 21,3866 | 21,46735 |
| Time in system | 65,2000587 | 65,13141 | 65,26871 | 65,11826 | 65,28186 |
| Customers in system at the end | 1,09974 | 1,0773 | 1,12218 | 1,073 | 1,12648 |
| Customers in check in queue | 4,21996789 | 4,19562 | 4,24432 | 4,19096 | 4,24898 |
| Time in check in queue | 12,42412602 | 12,35865 | 12,4896 | 12,34611 | 12,50214 |
| Customers in payment queue | 0,132749428 | 0,13248 | 0,13302 | 0,13243 | 0,13307 |
| Time in payment in queue | 0,408813043 | 0,40804 | 0,40959 | 0,40789 | 0,40973 |
| Customers in parking lot | 1,099176212 | 1,09692 | 1,10144 | 1,09648 | 1,10187 |
| Time in parking lot | 2,856323768 | 2,85066 | 2,86199 | 2,84957 | 2,86307 |
| Free clerks | 1,673115986 | 1,67136 | 1,67487 | 1,67103 | 1,6752 |
| Free mechanics group 1 | 2,200561084 | 2,19634 | 2,20478 | 2,19554 | 2,20558 |
| Free mechanics group 2 | 1,558435019 | 1,55497 | 1,5619 | 1,55431 | 1,56256 |
| Labour costs | 36000 |  |  |  |  |
| Number of replications | 50000 |  |  |  |  |

**Kombinácia 5/12/6**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 156,18744 | 156,09575 | 156,27913 | 156,07819 | 156,29669 |
| Customers departed | 155,00242 | 154,92224 | 155,0826 | 154,90689 | 155,09795 |
| Customers in system | 21,50374621 | 21,46973 | 21,53776 | 21,46322 | 21,54428 |
| Time in system | 65,45285351 | 65,3839 | 65,52181 | 65,37069 | 65,53501 |
| Customers in system at the end | 1,18502 | 1,16197 | 1,20807 | 1,15756 | 1,21248 |
| Customers in check in queue | 4,265641008 | 4,2412 | 4,29008 | 4,23652 | 4,29476 |
| Time in check in queue | 12,56631292 | 12,50054 | 12,63208 | 12,48795 | 12,64468 |
| Customers in payment queue | 0,131396567 | 0,13113 | 0,13167 | 0,13108 | 0,13172 |
| Time in payment in queue | 0,405015516 | 0,40424 | 0,40579 | 0,4041 | 0,40594 |
| Customers in parking lot | 1,144192483 | 1,14184 | 1,14655 | 1,14139 | 1,147 |
| Time in parking lot | 2,991328166 | 2,98538 | 2,99727 | 2,98425 | 2,99841 |
| Free clerks | 1,675157114 | 1,6734 | 1,67691 | 1,67307 | 1,67725 |
| Free mechanics group 1 | 2,471938637 | 2,46723 | 2,47664 | 2,46633 | 2,47755 |
| Free mechanics group 2 | 1,296290865 | 1,29329 | 1,29929 | 1,29272 | 1,29987 |
| Labour costs | 35500 |  |  |  |  |
| Number of replications | 50000 |  |  |  |  |

**Kombinácia 5/12/7**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 156,25911 | 156,19424 | 156,32398 | 156,18181 | 156,33641 |
| Customers departed | 155,85675 | 155,79527 | 155,91823 | 155,7835 | 155,93 |
| Customers in system | 20,28940804 | 20,26874 | 20,31008 | 20,26478 | 20,31404 |
| Time in system | 61,85745422 | 61,81726 | 61,89765 | 61,80956 | 61,90535 |
| Customers in system at the end | 0,40236 | 0,39354 | 0,41118 | 0,39185 | 0,41287 |
| Customers in check in queue | 3,254061186 | 3,24013 | 3,26799 | 3,23746 | 3,27066 |
| Time in check in queue | 9,586011719 | 9,54855 | 9,62347 | 9,54138 | 9,63064 |
| Customers in payment queue | 0,150027079 | 0,14981 | 0,15024 | 0,14977 | 0,15029 |
| Time in payment in queue | 0,459297039 | 0,4587 | 0,4599 | 0,45858 | 0,46001 |
| Customers in parking lot | 0,891465093 | 0,88994 | 0,89299 | 0,88965 | 0,89328 |
| Time in parking lot | 2,219233517 | 2,21554 | 2,22293 | 2,21483 | 2,22364 |
| Free clerks | 1,670414258 | 1,66915 | 1,67168 | 1,66891 | 1,67192 |
| Free mechanics group 1 | 2,829165962 | 2,82611 | 2,83222 | 2,82553 | 2,83281 |
| Free mechanics group 2 | 1,850457544 | 1,84788 | 1,85303 | 1,84739 | 1,85353 |
| Labour costs | 37500 |  |  |  |  |
| Number of replications | 100000 |  |  |  |  |

**Kombinácia 5/12/8**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 156,2695 | 156,17768 | 156,36132 | 156,1601 | 156,3789 |
| Customers departed | 156,14486 | 156,05477 | 156,23495 | 156,03752 | 156,2522 |
| Customers in system | 19,46937626 | 19,44428 | 19,49448 | 19,43947 | 19,49928 |
| Time in system | 59,45280487 | 59,40651 | 59,4991 | 59,39765 | 59,50796 |
| Customers in system at the end | 0,12464 | 0,1184 | 0,13088 | 0,1172 | 0,13208 |
| Customers in check in queue | 2,60413795 | 2,58832 | 2,61996 | 2,58529 | 2,62299 |
| Time in check in queue | 7,690776628 | 7,64822 | 7,73333 | 7,64007 | 7,74148 |
| Customers in payment queue | 0,165818512 | 0,16547 | 0,16617 | 0,1654 | 0,16624 |
| Time in payment in queue | 0,505644629 | 0,50471 | 0,50658 | 0,50453 | 0,50676 |
| Customers in parking lot | 0,69605145 | 0,69419 | 0,69791 | 0,69383 | 0,69827 |
| Time in parking lot | 1,637086578 | 1,63278 | 1,64139 | 1,63196 | 1,64221 |
| Free clerks | 1,669254282 | 1,66745 | 1,67106 | 1,66711 | 1,6714 |
| Free mechanics group 1 | 3,129670644 | 3,12582 | 3,13353 | 3,12508 | 3,13426 |
| Free mechanics group 2 | 2,482475313 | 2,47824 | 2,48671 | 2,47743 | 2,48752 |
| Labour costs | 39500 |  |  |  |  |
| Number of replications | 50000 |  |  |  |  |

**Kombinácia 5/13/7**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 156,22646 | 156,13482 | 156,3181 | 156,11727 | 156,33565 |
| Customers departed | 156,08602 | 155,99619 | 156,17585 | 155,97899 | 156,19305 |
| Customers in system | 19,51247349 | 19,48726 | 19,53769 | 19,48243 | 19,54252 |
| Time in system | 59,59580346 | 59,54916 | 59,64245 | 59,54023 | 59,65138 |
| Customers in system at the end | 0,14044 | 0,1342 | 0,14668 | 0,13301 | 0,14787 |
| Customers in check in queue | 2,623732447 | 2,60785 | 2,63961 | 2,60481 | 2,64265 |
| Time in check in queue | 7,750626847 | 7,70786 | 7,7934 | 7,69967 | 7,80159 |
| Customers in payment queue | 0,165148611 | 0,1648 | 0,1655 | 0,16473 | 0,16556 |
| Time in payment in queue | 0,503880694 | 0,50295 | 0,50481 | 0,50277 | 0,50499 |
| Customers in parking lot | 0,726123808 | 0,72417 | 0,72808 | 0,72379 | 0,72846 |
| Time in parking lot | 1,723649027 | 1,71908 | 1,72821 | 1,71821 | 1,72909 |
| Free clerks | 1,669970828 | 1,66817 | 1,67177 | 1,66783 | 1,67212 |
| Free mechanics group 1 | 3,479056379 | 3,47473 | 3,48339 | 3,4739 | 3,48422 |
| Free mechanics group 2 | 2,136629665 | 2,13285 | 2,14041 | 2,13212 | 2,14114 |
| Labour costs | 39000 |  |  |  |  |
| Number of replications | 50000 |  |  |  |  |

**Kombinácia 6/11/7**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 156,2591 | 156,19421 | 156,32399 | 156,18178 | 156,33642 |
| Customers departed | 155,38135 | 155,32292 | 155,43978 | 155,31173 | 155,45097 |
| Customers in system | 21,3961748 | 21,37355 | 21,4188 | 21,36922 | 21,42313 |
| Time in system | 65,16930661 | 65,12469 | 65,21392 | 65,11615 | 65,22246 |
| Customers in system at the end | 0,87775 | 0,8639 | 0,8916 | 0,86125 | 0,89425 |
| Customers in check in queue | 3,767664488 | 3,75227 | 3,78306 | 3,74933 | 3,786 |
| Time in check in queue | 11,10786542 | 11,06659 | 11,14914 | 11,05869 | 11,15704 |
| Customers in payment queue | 0,461695279 | 0,46105 | 0,46234 | 0,46093 | 0,46247 |
| Time in payment in queue | 1,423464928 | 1,42155 | 1,42538 | 1,42118 | 1,42575 |
| Customers in parking lot | 1,203408767 | 1,20129 | 1,20552 | 1,20089 | 1,20593 |
| Time in parking lot | 3,104326838 | 3,09911 | 3,10954 | 3,09811 | 3,11054 |
| Free clerks | 2,610234538 | 2,60899 | 2,61148 | 2,60875 | 2,61172 |
| Free mechanics group 1 | 2,186965681 | 2,18395 | 2,18998 | 2,18337 | 2,19056 |
| Free mechanics group 2 | 1,565718585 | 1,56324 | 1,5682 | 1,56276 | 1,56867 |
| Labour costs | 37100 |  |  |  |  |
| Number of replications | 100000 |  |  |  |  |

**Kombinácia 6/12/7**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 156,28074 | 156,21596 | 156,34552 | 156,20355 | 156,35793 |
| Customers departed | 156,01227 | 155,9498 | 156,07474 | 155,93784 | 156,0867 |
| Customers in system | 20,21002784 | 20,19117 | 20,22889 | 20,18756 | 20,2325 |
| Time in system | 61,68141029 | 61,64624 | 61,71658 | 61,6395 | 61,72332 |
| Customers in system at the end | 0,26847 | 0,26174 | 0,2752 | 0,26045 | 0,27649 |
| Customers in check in queue | 2,788413852 | 2,77672 | 2,80011 | 2,77448 | 2,80235 |
| Time in check in queue | 8,241694115 | 8,21029 | 8,2731 | 8,20428 | 8,27911 |
| Customers in payment queue | 0,473680348 | 0,47298 | 0,47438 | 0,47285 | 0,47451 |
| Time in payment in queue | 1,454184548 | 1,45214 | 1,45623 | 1,45175 | 1,45662 |
| Customers in parking lot | 0,966423993 | 0,9644 | 0,96845 | 0,96401 | 0,96883 |
| Time in parking lot | 2,381912229 | 2,3771 | 2,38672 | 2,37618 | 2,38764 |
| Free clerks | 2,607277302 | 2,60601 | 2,60854 | 2,60577 | 2,60879 |
| Free mechanics group 1 | 2,813516479 | 2,81045 | 2,81658 | 2,80987 | 2,81716 |
| Free mechanics group 2 | 1,861890849 | 1,85929 | 1,86449 | 1,8588 | 1,86499 |
| Labour costs | 38600 |  |  |  |  |
| Number of replications | 100000 |  |  |  |  |

## Metóda hľadania riešenia a odporúčania

Hľadanie optimálneho riešenia sme začali s kombináciou zamestnancov 100/100/100 a podľa počtu voľných zamestnancov sme znížili počty. Tento počet sme ďalej upravili podľa hodnôt z udalostnej simulácie a pridali viac zamestnancov. Ďalej sme robili experimenty s týmito počtami a došli sme k záveru, že riešenie, ktoré nám zabezpečí splnenie podmienok a vyjde najlacnejšie je pre kombináciu zamestnancov 5 prijímacích technikov, 12 mechanikov bez certifikátu a 7 mechanikov s certifikátom. Táto kombinácia stojí 37500€.

## Grafy

Graf závislosti počtu prijímacích technikov a zákazníkov v rade na prebratie prudko klesá a na hranici 7 technikov sa ustaľuje. Počet mechanikov sme zvolili na základe odporúčaného riešenia a to 12/7.

Obrázok, na ktorom je text, vývoj, rad, diagram

Automaticky generovaný popis

Graf závislosti počtu mechanikov a času v prevádzke klesá pomalšie a pri počte mechanikov bez certifikátu 21 sa začína ustaľovať. Počet mechanikov s certifikátom je v pomere 1:2 ku mechanikom bez certifikátu. Zvolený počet pokladníkov je 10.Obrázok, na ktorom je text, rad, vývoj, diagram

Automaticky generovaný popis

## Experimenty – zvýšený vstupný tok

**Kombinácia 7/15/9**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 193,4722 | 193,3286 | 193,6159 | 193,301 | 193,6434 |
| Customers departed | 193,0544 | 192,9104 | 193,1985 | 192,8828 | 193,2261 |
| Customers in system | 24,75284 | 24,71076 | 24,79492 | 24,70271 | 24,80298 |
| Time in system | 61,09758 | 61,03052 | 61,16464 | 61,01768 | 61,17748 |
| Customers in system at the end | 0,41776 | 0,38628 | 0,44924 | 0,38025 | 0,45527 |
| Customers in check in queue | 3,526603 | 3,49749 | 3,55571 | 3,49192 | 3,56129 |
| Time in check in queue | 8,480535 | 8,41599 | 8,54508 | 8,40363 | 8,55743 |
| Customers in payment queue | 0,599259 | 0,5976 | 0,60091 | 0,59729 | 0,60123 |
| Time in payment in queue | 1,486154 | 1,48228 | 1,49003 | 1,48153 | 1,49078 |
| Customers in parking lot | 0,793726 | 0,79032 | 0,79713 | 0,78967 | 0,79778 |
| Time in parking lot | 1,56357 | 1,55669 | 1,57045 | 1,55538 | 1,57176 |
| Free clerks | 2,82779 | 2,82495 | 2,83063 | 2,82441 | 2,83117 |
| Free mechanics group 1 | 3,678209 | 3,67169 | 3,68473 | 3,67044 | 3,68598 |
| Free mechanics group 2 | 2,570955 | 2,56436 | 2,57755 | 2,5631 | 2,57881 |
| Labour costs | 48200 |  |  |  |  |
| Number of replications | 25000 |  |  |  |  |

**Kombinácia 5/12/7**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 193,4344 | 193,3322 | 193,5365 | 193,3127 | 193,5561 |
| Customers departed | 178,3202 | 178,2803 | 178,3602 | 178,2726 | 178,3678 |
| Customers in system | 35,14852 | 35,09474 | 35,2023 | 35,08444 | 35,2126 |
| Time in system | 86,00033 | 85,90825 | 86,0924 | 85,89062 | 86,11003 |
| Customers in system at the end | 15,11416 | 15,02887 | 15,19945 | 15,01254 | 15,21578 |
| Customers in check in queue | 14,48877 | 14,44019 | 14,53735 | 14,43089 | 14,54665 |
| Time in check in queue | 34,82795 | 34,72786 | 34,92804 | 34,70869 | 34,94721 |
| Customers in payment queue | 0,195438 | 0,19515 | 0,19573 | 0,19509 | 0,19578 |
| Time in payment in queue | 0,523285 | 0,52252 | 0,52405 | 0,52238 | 0,52419 |
| Customers in parking lot | 1,285013 | 1,28373 | 1,2863 | 1,28348 | 1,28654 |
| Time in parking lot | 3,097899 | 3,09491 | 3,10089 | 3,09434 | 3,10146 |
| Free clerks | 1,045926 | 1,04452 | 1,04733 | 1,04426 | 1,0476 |
| Free mechanics group 1 | 1,35528 | 1,35235 | 1,35821 | 1,35179 | 1,35877 |
| Free mechanics group 2 | 0,870153 | 0,86832 | 0,87199 | 0,86797 | 0,87234 |
| Labour costs | 37500 |  |  |  |  |
| Number of replications | 50000 |  |  |  |  |

**Kombinácia 8/13/8**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 193,3877 | 193,2856 | 193,4898 | 193,2661 | 193,5094 |
| Customers departed | 190,1029 | 190,0266 | 190,1791 | 190,012 | 190,1937 |
| Customers in system | 28,72655 | 28,68314 | 28,76996 | 28,67482 | 28,77827 |
| Time in system | 70,60051 | 70,52758 | 70,67344 | 70,51362 | 70,6874 |
| Customers in system at the end | 3,28486 | 3,242 | 3,32772 | 3,23379 | 3,33593 |
| Customers in check in queue | 7,046526 | 7,01325 | 7,0798 | 7,00688 | 7,08617 |
| Time in check in queue | 16,91381 | 16,84134 | 16,98628 | 16,82746 | 17,00016 |
| Customers in payment queue | 0,513679 | 0,51278 | 0,51458 | 0,51261 | 0,51475 |
| Time in payment in queue | 1,294142 | 1,29192 | 1,29636 | 1,2915 | 1,29679 |
| Customers in parking lot | 1,419052 | 1,41656 | 1,42154 | 1,41608 | 1,42202 |
| Time in parking lot | 3,123589 | 3,11838 | 3,1288 | 3,11738 | 3,1298 |
| Free clerks | 3,778554 | 3,77668 | 3,78043 | 3,77632 | 3,78079 |
| Free mechanics group 1 | 2,101776 | 2,09717 | 2,10638 | 2,09629 | 2,10727 |
| Free mechanics group 2 | 1,412021 | 1,4087 | 1,41534 | 1,40807 | 1,41597 |
| Labour costs | 44300 |  |  |  |  |
| Number of replications | 50000 |  |  |  |  |

**Kombinácia 9/13/8**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 193,4906 | 193,3886 | 193,5926 | 193,3691 | 193,6121 |
| Customers departed | 190,1981 | 190,1219 | 190,2743 | 190,1073 | 190,2889 |
| Customers in system | 28,70577 | 28,66214 | 28,7494 | 28,65378 | 28,75775 |
| Time in system | 70,50117 | 70,42767 | 70,57466 | 70,4136 | 70,58873 |
| Customers in system at the end | 3,29248 | 3,24981 | 3,33515 | 3,24164 | 3,34332 |
| Customers in check in queue | 6,995033 | 6,96161 | 7,02846 | 6,95521 | 7,03486 |
| Time in check in queue | 16,77449 | 16,70161 | 16,84738 | 16,68765 | 16,86134 |
| Customers in payment queue | 0,489106 | 0,48823 | 0,48998 | 0,48806 | 0,49015 |
| Time in payment in queue | 1,231859 | 1,22968 | 1,23403 | 1,22927 | 1,23445 |
| Customers in parking lot | 1,467558 | 1,46499 | 1,47013 | 1,4645 | 1,47062 |
| Time in parking lot | 3,230903 | 3,22553 | 3,23628 | 3,2245 | 3,23731 |
| Free clerks | 4,713837 | 4,71196 | 4,71571 | 4,7116 | 4,71607 |
| Free mechanics group 1 | 2,099605 | 2,095 | 2,10421 | 2,09412 | 2,10509 |
| Free mechanics group 2 | 1,405693 | 1,40237 | 1,40901 | 1,40174 | 1,40965 |
| Labour costs | 45400 |  |  |  |  |
| Number of replications | 50000 |  |  |  |  |

**Kombinácia 9/14/8**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 193,4433 | 193,3414 | 193,5453 | 193,3218 | 193,5648 |
| Customers departed | 192,0642 | 191,9757 | 192,1528 | 191,9587 | 192,1698 |
| Customers in system | 26,801 | 26,76257 | 26,83944 | 26,7552 | 26,8468 |
| Time in system | 65,96154 | 65,89834 | 66,02473 | 65,88624 | 66,03684 |
| Customers in system at the end | 1,3791 | 1,35289 | 1,40531 | 1,34787 | 1,41033 |
| Customers in check in queue | 5,217631 | 5,19006 | 5,2452 | 5,18478 | 5,25048 |
| Time in check in queue | 12,49463 | 12,4342 | 12,55506 | 12,42262 | 12,56663 |
| Customers in payment queue | 0,502203 | 0,50126 | 0,50315 | 0,50108 | 0,50333 |
| Time in payment in queue | 1,253499 | 1,2512 | 1,2558 | 1,25076 | 1,25624 |
| Customers in parking lot | 1,280747 | 1,27799 | 1,28351 | 1,27746 | 1,28404 |
| Time in parking lot | 2,719756 | 2,71412 | 2,72539 | 2,71304 | 2,72647 |
| Free clerks | 4,70599 | 4,70404 | 4,70793 | 4,70367 | 4,70831 |
| Free mechanics group 1 | 2,712504 | 2,70759 | 2,71742 | 2,70664 | 2,71836 |
| Free mechanics group 2 | 1,674502 | 1,6709 | 1,67811 | 1,67021 | 1,6788 |
| Labour costs | 46900 |  |  |  |  |
| Number of replications | 50000 |  |  |  |  |
| Customers arrived | 193,4433 | 193,3414 | 193,5453 | 193,3218 | 193,5648 |

**Kombinácia 10/14/9**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Name | Mean | Lower 90% CI | Upper 90% CI | Lower 95% CI | Upper 95% CI |
| Customers arrived | 193,5142 | 193,4118 | 193,6166 | 193,3922 | 193,6362 |
| Customers departed | 193,0446 | 192,9479 | 193,1414 | 192,9293 | 193,16 |
| Customers in system | 25,23926 | 25,20629 | 25,27222 | 25,19998 | 25,27853 |
| Time in system | 62,20849 | 62,15642 | 62,26055 | 62,14645 | 62,27052 |
| Customers in system at the end | 0,46954 | 0,45531 | 0,48377 | 0,45258 | 0,4865 |
| Customers in check in queue | 3,835983 | 3,81408 | 3,85789 | 3,80988 | 3,86208 |
| Time in check in queue | 9,179427 | 9,13135 | 9,2275 | 9,12215 | 9,2367 |
| Customers in payment queue | 0,492375 | 0,49139 | 0,49336 | 0,49121 | 0,49354 |
| Time in payment in queue | 1,223449 | 1,22107 | 1,22583 | 1,22062 | 1,22628 |
| Customers in parking lot | 1,08856 | 1,08572 | 1,0914 | 1,08518 | 1,09194 |
| Time in parking lot | 2,214481 | 2,20886 | 2,2201 | 2,20779 | 2,22117 |
| Free clerks | 5,638552 | 5,63656 | 5,64055 | 5,63618 | 5,64093 |
| Free mechanics group 1 | 3,065767 | 3,06118 | 3,07035 | 3,06031 | 3,07123 |
| Free mechanics group 2 | 2,231452 | 2,22719 | 2,23571 | 2,22638 | 2,23653 |
| Labour costs | 50000 |  |  |  |  |
| Number of replications | 50000 |  |  |  |  |
| Customers arrived | 193,5142 | 193,4118 | 193,6166 | 193,3922 | 193,6362 |

## Metóda hľadania riešenia a odporúčania

Hľadanie optimálneho riešenia sme začali vynásobením počtu odporúčaných zamestnancov pre normálny tok zákazníkov indexom zväčšenia tohto toku. Ďalej sme robili experimenty v okolí tohto riešenia a našli sme odporúčané riešenie, a to 7 prijímacích technikov, 15 mechanikov bez certifikátu a 9 mechanikov s certifikátom.

## Grafy

Graf závislosti počtu prijímacích technikov a zákazníkov v rade na prebratie prudko klesá a na hranici 7 technikov sa ustaľuje. Počet mechanikov sme zvolili na základe odporúčaného riešenia a to 15/9.

Obrázok, na ktorom je text, vývoj, rad, diagram

Automaticky generovaný popis

Graf závislosti počtu mechanikov a času v prevádzke klesá pomalšie a pri počte mechanikov bez certifikátu 21 sa začína ustaľovať. Počet mechanikov s certifikátom je v pomere 1:2 ku mechanikom bez certifikátu. Zvolený počet pokladníkov je 10.

Obrázok, na ktorom je text, vývoj, rad, diagram

Automaticky generovaný popis

# Záver

Pomocou simulačnej štúdie sme zistili potrebné počty pracovníkov pre dielňu STK, tak aby boli splnené podmienky a stálo nás to čo najmenej.

Odporúčané riešenie pre aktuálnu návštevnosť je: 5 prijímacích technikov, 12 mechanikov bez certifikátu a 7 technikov s certifikátom. Toto riešenie vyjde na 37 500 €.

Odporúčané riešenie pre zvýšenú návštevnosť je: 7 prijímacích technikov, 15 mechanikov bez certifikátu a 9 technikov s certifikátom. Toto riešenie vyjde na 48 200 €.