Examining the Impact of Metro Expansion and Automation on Driver Resources: A Case Study of the West Midlands Metro Network

By Shinde, P. & Marinov, M., ESSCM, Aston University

ABSTRACT

Public transport networks are expanding while adopting automation, necessitating examination of impacts on human resources like metro drivers. This study analysed the West Midlands Metro Network to determine effects of expansion and automation on driver resources. Using data-driven probabilistic forecasting, potential automated capabilities were evaluated for a proposed metro expansion to project timelines and analyse resultant role changes for drivers. Findings indicate beginning with partial automation enables infrastructure stabilization before progressing to fully driverless systems. The graduated timeline balances technology adoption and change management. By forecasting automation phases and visualizing declining operational roles, the study provides transportation authority's actionable insights on sustainably evolving skills and workforce needs amidst automation. Starting with partial automation allows time for measured transition support before driverless operation. The research contributes data-driven, localized projections to guide strategic planning for metro automation implementations and mitigate labour disruptions.

KEYWORDS

metro automation; driver resources; metro expansion; metro organization.

1. INTRODUCTION

The swift integration of technology and automation within the metro transport system has created an urgent demand to look at its impact on staff and enhance their skills in order to mitigate employment losses and adapt to shifting requirements.

1.1 Background

Automated driving systems have gained potential in research studies since they have been considered to be associated with having the ability to possess better safety in driving, increased convenience in travelling, and higher efficiency in energy, which has also caused systems to have more interest in research. The progress in technologies, including advanced sensing, robust vehicle control, intelligent decision-making, etc., has accelerated the development of vehicles that are equipped with automated driving systems [1].

Simultaneously, over the last several decades, the worldwide metro network has expanded significantly. The present report by UITP [2] reveals that as of the concluding day of the year 2020, the collective metro systems, comprising 193 entities, constituted an installed asset base of 731 lines, which spanned over a total length of 17,000 kilometres and encompassed nearly 13,000 stations. During the timeframe, including the beginning of 2018 and the end of 2020, a significant amount of new infrastructure, totalling roughly 3,300 km, was successfully constructed, and put into service with the aim of producing capital. This covers the growth of metro systems in numerous countries, including but not limited to China, India, Australia, Indonesia, Pakistan, and Qatar. The emphasis in these nations is on the opening of new metro lines as well as the expansion of existing ones in already-established metro cities. As per the statistics of light rail and tram passenger journeys, there was a notable surge in the usage of light rail and tram services in England until March 2022, with a recorded count of 171.5 million passenger journeys [3]. This figure signifies a more than twofold increase compared to the preceding year's count until March 2021.

On the other hand, outdated technology, such as manual ticketing systems, obsolete signalling systems, and inefficient energy management, have had a negative impact on the metro sector. The sector has made investments in several facets to strategize for the future. An illustrative instance is the situation in Copenhagen, Denmark, which offers substantiation that the implementation of automated metro lines has resulted in favourable consequences in relation to cost-effectiveness, capacity management, and operational flexibility [3].

The workforce has been seeing the effects of the transformations occurring within the metro industry. The metropolitan transport sector is seeing a notable transformation in labour market demand, particularly in occupations such as drivers, which are expected to undergo substantial changes in the next few decades [4]. The metro drivers could see a shift in their roles or could also have their roles completely vanished, while the manufacturers have already been creating driverless prototypes for the metro industry that could be launched on the tracks soon. Use of these technologies could mean that a driverless future lies on the horizon [5]; however, drivers possess unique skills and insights that can complement automated technologies, potentially influencing a collaborative future rather than entirely replacing human roles.

1.2 Motivation

The motivation for investigating the effects of metro expansion and automation on driver demands within the West Midlands metro system is rooted in the idea of "change." The phenomenon of change exerts a significant influence on various aspects of our society, industries, and daily existence. In the context of the metro transport system, change is on the horizon as a result of the growing use of technology and automation. This change possesses the capability to transform the way we travel, enhance safety measures, augment efficacy, and diminish environmental repercussions.

Nevertheless, the implementation of this change raises worries regarding the possible unemployment of metro drivers and the necessity of responding to evolving demands. The key lies in the need to acknowledge these concerns and devise strategies to augment the competencies of drivers, thereby securing their sustained significance in this dynamic sector. Furthermore, recognising the possible effects of adopting this change is crucial in order to make sound decisions regarding the prospects of metro transport.

1.3 Research significance

- This topic addresses the pressing issue of how metro expansion and automation will affect driver resources. The topic has contemporary significance since there is a growing global inclination towards the expansion of metro networks.
- This research offers unique insights into the impact of metro development and automation on driver resources in the West Midlands Metro Network via a case study analysis. The results of this study have the potential to serve as a valuable resource for other urban areas contemplating comparable expansions.
- Understanding the effects of metro development and automation on driver resources is crucial for making well-informed choices about public transportation planning and policymaking. This research addresses the existing knowledge gap in this field, therefore providing valuable insights for policymakers to enhance the effectiveness of their decision-making processes.
- This research has the potential to result in enhancements in resource allocation within metro networks, thereby ensuring the best utilisation of human resources while capitalising on technological breakthroughs such as automation.
- Examining the effect of metro expansion and automation on driver resources may provide valuable insights into the possible employment consequences for drivers within a sector that is becoming more automated. This analysis enables stakeholders to proactively anticipate and prepare for any necessary modifications or support measures that may be needed.
- This research topic holds practical implications for various entities involved in public transportation systems, including transportation authorities, transit operators, labour

unions, commuters, and other stakeholders. These entities stand to gain valuable insights into the potential impact of these changes on their respective interests.

- This research makes a valuable contribution to broader academic discussions surrounding sustainable development, efficient resource management, technology adoption trends, and workforce dynamics within evolving industries such as transport through an in-depth investigation of the West Midlands Metro Network's experience with expansion and automation.

2. LITERATURE REVIEW

The growth of urban rail transportation networks and the use of automation technology are two crucial factors impacting metro operations across the world. This review of the literature looks at significant studies on these themes and their implications for train drivers in particular. The paper summarises research regarding metro expansion, automation deployment techniques, consequences for labour roles, and linkages between both growth and technological advancement factors. Gaps in linking research ideas to localised situations and using quantitative approaches are noted. The review establishes the foundation for the subsequent methodology to be used.

2.1 Reason for the Expansion of the West Midlands Metro

According to Weerawat et al. [6], the expansion of the West Midlands Metro was based on an increase in the connectivity of the locations. The presence of railway tracks that are not in use currently at this location has caused there to be an increase in the need for expansion in the West Midlands Metro. The growth in demographics in this region has caused the development of the metro network's expansion plan. The increase in population makes the increase in railway connectivity necessary, thus justifying the expansion plan. The acceleration in urbanisation around the globe, according to Li et al. [7], has helped with continuous growth in the urban population, and it has led to an increase in the number of private vehicles, which has caused there to be much more traffic congestion in the global metropolitan cities. Globally, urban rail transit has been considered a form of public transportation that is efficient and helps reduce congestion in metropolises. In this case, the rapid growth in urbanisation and population has caused an increase in the need for expansion. Public transportation in the urban context has the ability to decrease dependence on automobiles, addressing different urban issues, including air pollution, traffic congestion, greenhouse gases, etc., [8]. This kind of transportation accessibility is provided by the expansion of the rail network.

2.2 Expansion plan

The West Midlands Metro envisions a substantial expansion, connecting key locations and serving the growing transportation needs of the region. As a foundation for this discussion, readers are encouraged to explore the comprehensive socio-economic impact assessment conducted by Gualtieri and Marinov in 2020 [9]. Their work, 'The Metro Network Extension in the West Midlands: A Socio-economic Impact Assessment,' provides in-depth insights into the extension of lines and networks as a whole, offering a detailed examination of the socio-economic implications of the metro network expansion.

Building on this prior study, we will now focus on the specific details of the expansion plan for the West Midlands Metro. The West Midlands Metro will serve over 80 tram stops, more than 20 transport interchanges, and link Wolverhampton, Birmingham, Dudley, Brierley Hill, Digbeth, North Solihull, Birmingham Airport, the NEC, and HS2 [10]. *Figure 1* shows the planned expansion map of West Midlands Metro.

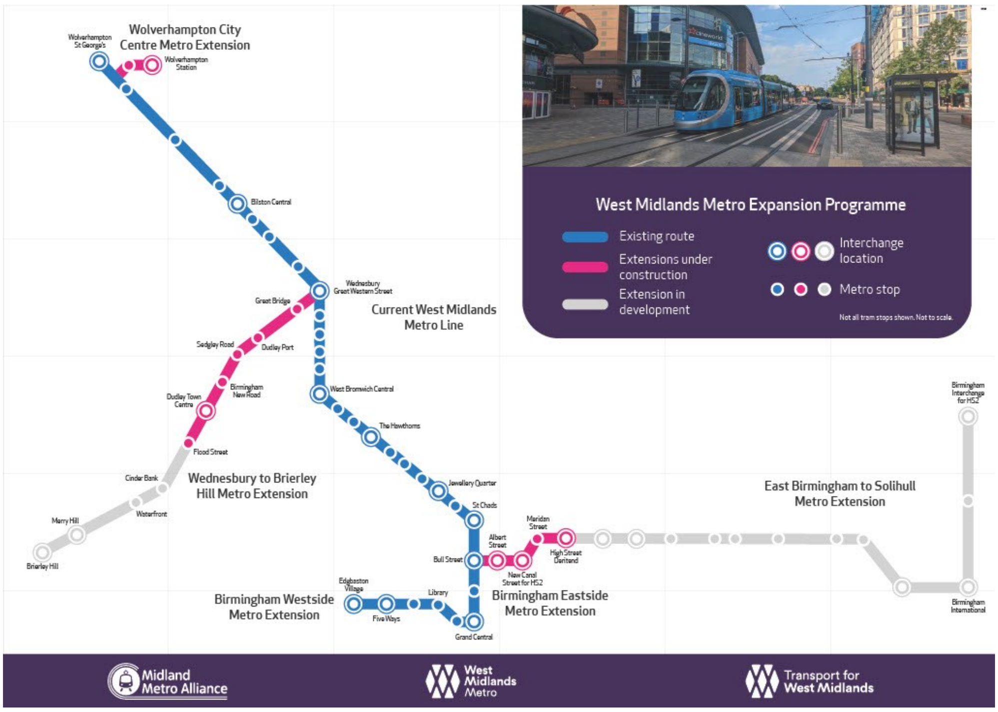

Figure 1 – Expansion map
Referred from West Midlands Metro [10]

2.3 Automation readiness factors for metro expansions

The Several studies have evaluated readiness factors that can determine appropriate timelines for implementing automation in metro systems. This provides perspective on the preparedness of the planned West Midlands metro expansions.

New metro lines designed with automation in mind from inception have fewer integration barriers versus retrofitting older systems [11]. However, even new infrastructure requires upgrading power, signals, and rolling stock for automation [12]. This indicates the West Midlands extensions would need phased enhancements despite their "greenfield" nature.

Small, automated metro networks can achieve faster transition times compared to larger complex systems [13]. The overall approximately 34km West Midlands expansions fall in the mid-range, suggesting a graduated implementation pace.

2.4 Levels of automation

Several functions within the sphere of train operations might potentially be automated, resulting in separate duties being assigned to workers in each situation. UITP provides the standard definition of Grades of Automation (GoA). *Table 1* depicts a full overview of the many levels, which are classified based on four unique criteria: setting a train in motion, stopping a train, door closure, and operation in the event of disruption.

Table 1 – Grades of train automation
Referred from Powell et al. [14].

Grade of Automation (GoA)	Type of train operation	Setting train in motion	Stopping train	Door closure	Operation in event of disruption	Example
GoA 0	Driver without ATP	Driver	Driver	Driver	Driver	On-street trams
GoA 1	Driver with ATP	Driver	Driver	Driver	Driver	Tyne and Wear Metro

GoA 2	ATP and ATO with driver	Automatic	Automatic	Driver	Driver	Paris Metro Line 3
GoA 3	DTO	Automatic	Automatic	Train attendant	Train attendant	Docklands Light Railway
GoA 4	UTO	Automatic	Automatic	Automatic	Automatic	Dubai Metro

The driver controls all vehicle operations in Grade 0 (GoA 0), which is a procedure that dates back to railway history. This strategy, however, is no longer common in current metro systems. Both Grades of Automation 1 (GoA 1) and 2 (GoA 2) require the presence of a driver on the train, as well as a specific amount of automated train protection (ATP) capabilities. Automatic Train Protection (ATP) is a safety feature that reduces the likelihood of a collision. It works by immediately deploying the brake mechanism if the train runs a red light or exceeds the specified speed limit. In GoA1, the train driver in the cabin has the responsibility for the entire train ride, including any adjustments to the speed, and an automated system is fitted for tracking compliance with the speed limits for the train. Furthermore, GoA 2 has automated train operation (ATO) to control train movement during normal operations. Automation levels 3 (GoA 3) and 4 (GoA 4) refer to the adoption of driverless or unattended train operations that do not require the presence of an on-board driver. The automated train protection (ATP) and autonomous train operation (ATO) functions, on the other hand, remain critical components of the system. The third version of the GoA system features an on-board attendant who oversees controlling door operations, offering passenger assistance, and assuming control of the train in the case of equipment failure. The operation of a train is totally automated in the context of GoA 4, since all four conditions indicated in *Table 1* may be met without the need for human presence on the train. The trains are efficiently monitored and managed by the staff situated in a remote-control centre. These technologies are used mainly for metros. Although this has diminished workload, it has been found that the increase in automation can cause failure performance to also decrease, thus increasing reaction times when unexpected critical information is provided [15].

2.5 Interactions between Automation and Driver Resources

Drivers represent the largest and most effective blue-collar occupation that is aimed at obsoletion with the increase in automation. The creation of driverless trains has caused many of their actions to become less necessary in metro rail. This has implied the need for upskilling and reskilling so that the skill gaps can be addressed regarding the adoption of new technologies and the development of digital skills, along with technological acceptance [16].

According to the precise definition provided by the Cambridge dictionary, "reskilling" refers to "the process of learning new skills so you can do a different job, or of training people to do a different job". When discussing the concept of "Upskilling," it refers to “the process of learning new skills or of teaching workers new skills”. According to Li [17], there is a need for reskilling and upskilling the workforce so that they can be acclimatised to Industry 4.0 technologies. Individuals and companies require an effective commitment to reskilling and upskilling so that career development can be possible.

Railway automation has changed the ways in which staff members of the rail industry can make contributions to the overall performance of the system and safety levels. They can affect the performance of the train drivers, their workload, their fatigue levels, their attention allocation, and their awareness regarding the situation [15].

However, according to Karvonen et al. [18], the drivers do not just operate the train on the track and the doors of the train at the stations but also contribute to other hidden but essential functions in the metro rail system. For instance, the drivers need to predict, make observations, make interpretations, and provide adequate responses to environmental cues. There are often unplanned situations that require the train drivers to board the metro system. This includes the unauthorised use of the emergency handle, which is when the driver has to check the train and reset the emergency handle. There can also be technical door issues when the train driver is required to contact the maintenance group and fix the door. Also, unauthorised people are present on the track this is when the driver is required to contact the maintenance group or traffic control. These are difficult operations to perform in the case of a driverless metro system. Thus, technologies cannot completely replace the drivers on all occasions, for instance, regarding the driver managing passengers, responding to any orders that are given by the train dispatcher, and so on, which cannot be taken up by the technology [19]. Also, there are other links of interaction with the other actors present within the metro system. These need to be considered before a fully automated metro system is adopted, since a lack of importance could cause the quality of service to be affected and could lead to safety problems. Driverless train operations could cause challenges in positions like the detection and management of emergencies. The driver may also need to perform physical activities in particular situations, like organised evacuation during accidents, which may require the driver's reflexes and physical prowess [19].

Thus, while some articles believe that drivers' roles are becoming obsolete in the face of the emergence of automation technologies, other articles pose an issue in this respect, contradicting the essential actions that require train drivers.

2.6 Literature gap

While significant research has been conducted examining the impact of automation on driver roles, the literature offers limited insights specific to drivers within expanding metro networks. Each metro line has unique characteristics in terms of network configuration, operational dynamics, ridership patterns, etc. Therefore, the impact of automation and expansion will vary across different metro systems, along with their implications for drivers. Most existing studies provide generalised perspectives [4, 10, 13, 14] without analysing impacts within realistic, localised scenarios. Considering the brisk growth of global metro infrastructure and the hastening pace of adoption of driverless train technologies, understanding the impacts on transportation labour forces for specific metro networks is increasingly pressing.

Additionally, existing works tend to be conceptual or survey-based without utilising quantitative modelling and forecasting approaches to project automation's timeline and subsequent changes to driver needs on a case-by-case basis. Generalisations cannot substitute for analysing impacts within realistic, localised scenarios.

Studies also usually look at either automation or expansions on their own, without looking at how they change things when they work together. One way to do this is to look at both expansion plans and gradational automation implementation roadmaps at the same time.

This research will fill in the gaps by doing a detailed case study of possible network expansions for the West Midlands Metro, along with accurate predictions of how automation will be added in stages. Outcomes seek to provide practical insights into changes facing drivers and also inform the timeline to implement supportive transition management. The research questions cut across broader studies by focusing on an explicitly defined localised context and employing mixed analytical methods.

3. METHODOLOGY

The methodology employed in this paper to achieve its objectives will be outlined in this section. In order to better understand the future of the metro system and its impact on drivers, a comprehensive analysis is being conducted. This analysis focuses on two main objectives: analysing possible expansion and examining how the evolving work profiles of drivers are influenced by the expansion and automation of the network. By delving into these areas, valuable insights can be gained to inform decision-making and ensure the smooth transition into a more advanced and efficient metro system. This section delves into an analysis of how the chosen methodology aligns with the research topics. The objective is to gain valuable insights into the dynamic transport sector.

3.1 Framework

The study was conducted in two phases to investigate the impact of expansion and automation on drivers in the West Midlands metro system.

Phase 1 involved conducting a comprehensive literature review to analyse potential extension strategies for the West Midlands metro line. The review aimed to gain insights into factors driving growth, potential development strategies, and the evaluation of extension impacts.

Phase 2 aims to:

- Forecast timelines for achieving various levels of automation on the extending metro line using a data-driven forecasting methodology.
- Observe the effects of automation on drivers' roles for each automation level.
- Determine when drivers will need upskilling or role transitions based on the forecasted timeline.

A data-driven forecasting methodology was used to project a probabilistic timeframe for attaining degrees of automation in the evolving West Midlands metro scenario over the coming years. Since historical data or trend information was lacking for this emerging application, an alternative approach known as data-driven forecasting was employed. This approach utilises available current data to generate forecasts in situations lacking historical trends.

3.2 Projection of timeframe

The methodology employed involves analysing previous case studies of metro networks that have successfully implemented automation in order to project a probabilistic timeframe for the West Midlands metro extension's achievement of various levels of automation. The methodology entails conducting a comprehensive review of research literature and industry reports that provide detailed information on the timelines and processes associated with the adoption of automation in metro systems worldwide.

The case studies are thoroughly examined based on a range of factors, such as:

- Automation level implemented (GoA Levels 1-4),
- The time period allocated for the planning and installation process,
- Metro Network Scale,
- Technological difficulties encountered,
- Implementation expenses

To conduct a comprehensive analysis of implementation factors, a selection of metro lines that have undergone recent automation are examined in closer detail. The chosen metro lines for this study include Singapore's North-East Line, Dubai's Red Line, and Beijing's Batong Line. Their timeframes combined will provide information for a projection model used in the West Midlands extension.

Case study: Singapore metro line

The North-East line in Singapore opened in 2003 with GoA2 automation, which allowed automated train control but still required onboard train captains [20]. In 2017, the process began to transition the line to GoA4 full driverless operation, which was completed in 2022 [20]. This upgrade took around 5 years from planning to full implementation and cost approximately SGD 25 million (approximately EUR 17 million) [21]. As one of Singapore's oldest lines at 20km and 16 stations, technical challenges included retrofitting legacy equipment.

Case study: Dubai metro line

The Red Line of Dubai was constructed using GoA2 automation at its start of operations in 2009. Testing for the GoA4 autonomous operation had begun by 2011. The comprehensive transformation was finished by the year 2015. The network's implementation duration of six years was deemed expeditious given its considerable scope, including a total length of 52 km, and accommodating 29 stations. The expenses surpassed a total of 7.6 billion US dollars (approximately 6.992 billion Euros). The hot heat in Dubai gave rise to initial technological challenges, but, overall, the newly developed infrastructure proved to be favourable for automation [22, 23].

Case study: China metro line

In 2015, the Batong line in Beijing had a substantial enhancement, resulting in the transfer from Grade of Automation (GoA) 2 to GoA 4. This improvement enabled the implementation of unattended train operations on the line. The line, which was first inaugurated in 2002, extends across 10 km and has a total of 7 stops. Despite the comparatively modest level of ridership, the retrofitting process was executed over a span of 18 months, incurring a total expenditure of CNY 461 million (approximately EUR 59.93 million). The update was deemed to have a relatively low technical difficulty, mostly owing to the size of the queue and the number of people it serves [24].

3.3 Plotting graph

Graphs are a fundamental tool in data visualisation and analysis, offering numerous benefits like visual representation, simplification, comparison, identification of trends, outliers, hypothesis testing, data exploration, decision-making, and communication with experts and non-expert audiences [25, 26, 27].

In the present discourse, a graphical representation is generated, wherein the vertical axis is designated as the Grades of Automation (GoA), while the horizontal axis denotes the forecasted years. The subject matter at hand pertains to the resultant patterns observed in the degree of automation and the corresponding role of drivers, which serve as the desired outcome and a topic of discourse.

3.4 Collection of results

The assessment of results demands the consideration of several factors. The following aspects are utilised as indicators to facilitate the quantification of the effectiveness and impact of specific factors: In order to assess the outcomes in the realm of automation, it is customary to consider three fundamental aspects: the trajectory of automation levels' implementation, the evolution of drivers' roles, and the determination of the breakeven point. The initial aspect, referred to as the trend in the implementation of levels of automation, serves as a crucial component for gaining valuable insights pertaining to the advancement and acceptance of automated systems. Through a comprehensive analysis of the process of automation implementation, it is possible to ascertain the degree to which organisations are adopting and integrating technological advancements. The assessment of the pace of automation integration is conducted to gain insights into the overall impact and potential benefits derived from these efforts. This aspect focuses on examining the rate at which automation is being integrated over a specific period. In order to obtain a comprehensive comprehension of the evolving dynamics, the second aspect, namely the trend in drivers' responsibilities, is analysed. Finally, the breakeven point is determined to offer a quantitative estimate of the point at which demand for drivers equalises. All of these characteristics are taken into account as basic benchmarks when conducting a thorough review of the results.

3.5 Limitations

- Projections Validation: There was no independent verification or evaluation of the projections used in this study. As a result, their accuracy and dependability may be dubious.
- Technology Change Uncertainty: The future direction of technological breakthroughs is necessarily unclear. As a result, unanticipated technological advancements could have an impact on the forecasts generated by this research, which could affect the accuracy of the findings.
- Contextual Variability: It is crucial to highlight that the results and conclusions of this study may alter across various contexts, such as geographical areas, passenger flow, or unique market situations. Therefore, when applying the findings to particular scenarios, care should be taken.

The forecasting methodology employed in this study utilises the existing data to generate an informed estimation regarding the progression of automation levels in the expanded West Midlands metro.

4. RESULTS

The results and analyses of the phases indicated in the methodology section are presented in this section. Each phase attempts to investigate various elements of the West Midlands metro system, ranging from future expansions to changing work profiles for drivers as a result of automation implementation.

4.1 Potential extension of the metro network

The exploration of the potential extension of the West Midlands metro network through a literature review shed light on important considerations and outcomes.

The review indicated that successful extensions can lead to increased ridership, improved connectivity, and positive economic outcomes.

In terms of automation readiness factors, the successful integration of automation technologies in metro expansions necessitates careful planning and phased enhancements. While new metro lines designed with automation in mind from their inception tend to encounter fewer integration challenges, even new infrastructure requires upgrades in power systems, signalling, and rolling stock to accommodate automation seamlessly. This emphasises the importance of meticulous planning and the phased introduction of automation technologies, even for "greenfield" expansions.

The findings from the literature review highlighted that careful planning and thorough analysis of potential extensions are crucial for achieving the desired benefits. Learning from successful case studies in other cities can provide valuable insights for the West Midlands metro line.

4.2 Automation impact on driver role

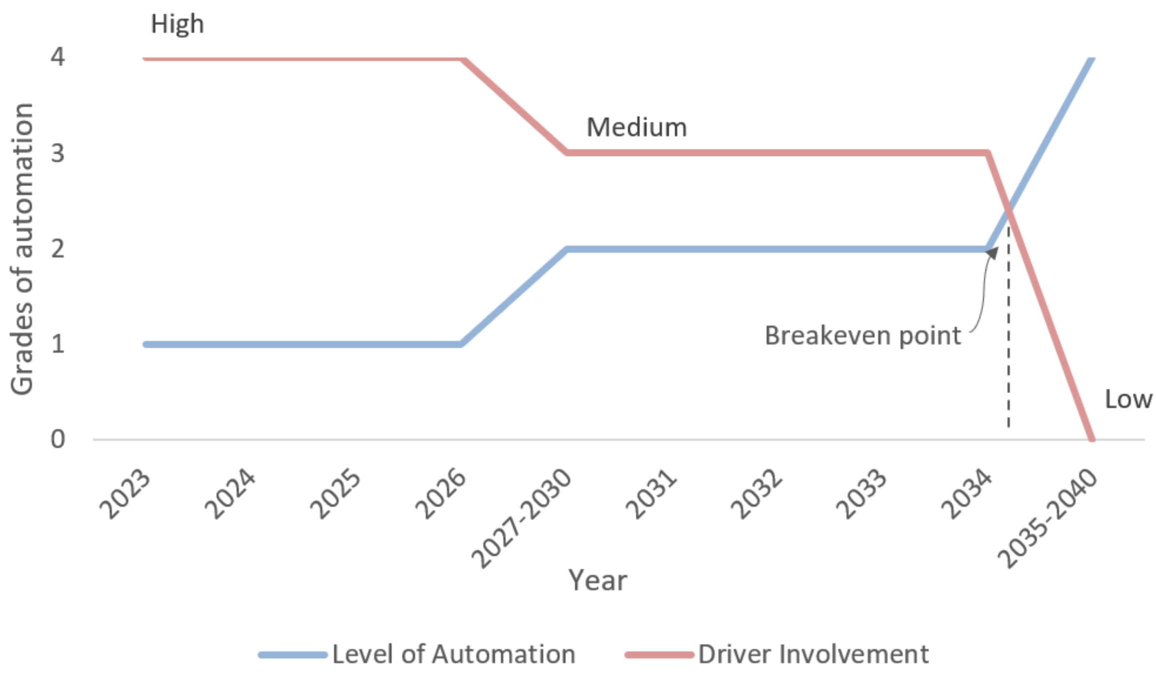

Figure 2: Projected automation timeline and its impact on driver resources

Figure 2 shows the projected timeline for implementing different automation levels across the planned West Midlands metro expansion projects and the associated impact on driver roles.

The projections are based on data from the following metro automation case studies:

Table 2 – Metro automation case study data for projections

Case Studies / Factors	North-East line	Red line	Batong line

Automation level implemented	GoA2 – GoA4	GoA2 – GoA4	GoA2 – GoA4
Time period to upgrade (years)	5	6	1.6
Metro Network Scale (km)	20	52	10

GoA2 partial automation is forecast to be implemented between 2027 and 2030, depending on the scale of each line. Full GoA4 driverless operation is estimated to be attained between 2035 and 2040, based on the complexity factors. The forecasts are justified by the case study timelines for comparable metro scales and complexities.

The omission of an intermediate GoA3 stage reflects industry trends. Many metro systems have skipped conditional automation and shifted directly from GoA2 to full GoA4 driverless operation for maximum economic benefit. This aligns with the ambitious, yet pragmatic approach taken in the projections.

The analysis indicates the expansions will commence with partial automation, providing time to stabilise infrastructure before pursuing more advanced driverless capability. The graduated timeline balances swift technology adoption with change management imperatives for the metro organisation and its employee base.

The phased automation transition is projected to significantly impact driver roles and requirements. Under GoA2, drivers will need to be trained to monitor and manage automated systems instead of manually operating trains. As automation increases and shifts to GoA4, their focus will shift towards supervision, anomaly detection, and passenger assistance.

The breakeven threshold shown in Figure 2 suggests that drivers will need to either take on new non-operating roles or be redeployed or retrenched prior to this breakeven point. New positions may involve remote monitoring, on-demand passenger guidance, and platform operations. Retention programmes and re-training will be critical to managing employment impacts.

Overall, the graphical representation of the forecasted years and automation levels demonstrated a clear trend: as automation increases, the roles of drivers decrease. This visualisation serves as a powerful tool for decision-makers to anticipate changes in the workforce and plan for skill enhancements and training programmes, keeping timelines in mind.

5. DISCUSSION

When developing infrastructure, such as the proposed West Midlands Metro expansions, it is essential to meticulously evaluate the many aspects that impact the incorporation of automation. Both the literature review and case studies emphasise the significance of adopting a gradual and phased methodology for improving power, signalling, and rolling stock systems rather than following a strategy of large-scale and instantaneous deployment. The integration of modern technology necessitates continuous updates to new lines in order to ensure smooth compatibility over time. By using a progressive methodology, it becomes feasible to methodically address technological obstacles while concurrently guaranteeing the reliability of new infrastructure before progressing towards more advanced stages of automation. The evaluation of such initiatives has shed light on the need for detailed planning for expansions and the possibility of automation in such endeavours.

The anticipated schedule that predicts the gradual integration of automated grading systems provides significant information about the preparedness of the workforce. The initiation of partial automation inside the GoA2 system allows for the attainment of operational stability before the eventual shift to full driverless capabilities. The concept of incremental growth aims to achieve a harmonious equilibrium between rapid implementation and the demands associated with change management. The roadmap enforces stringent governance protocols to authorise the progression of each step only upon thorough verification of severe requirements. However, it focuses on ambitious timetables that align with benchmark metro systems. By using rigorous project management strategies and effectively mitigating risks, this roadmap has the potential to guide the growth of the West Midlands metro towards attaining exceptional levels of automation, passenger service, and operational excellence on a global scale. The use of a staged strategy mitigates the risks associated with this intricate shift while simultaneously prioritising safety.

The examination of trends suggests that the changing responsibilities of drivers require the implementation of proactive initiatives. The significance of reskilling and upskilling becomes apparent when contemplating the supervision of automated activities and the potential occurrence of obsolescence. The effective facilitation of the integration stage can also be achieved through the implementation of new supervisory and customer service positions. Additionally, it is crucial to provide programmes that support affected workers in order to effectively manage the disruptions that may arise. Most importantly, higher education in the rail industry can be updated to match the industry requirements. Engaging stakeholders is important as it fosters understanding of the anticipated effects of advanced metro automation.

In order to effectively navigate the challenges and opportunities presented by the expansion of metro networks and automation technologies, it is essential to adopt a well-rounded and equitable approach. This approach should aim to maximise the advantages brought about by these advancements, while also taking into account the potential negative effects on the workforce. To achieve this, it is important to implement timely *reskilling* or *upskilling* initiatives and comprehensive change management programmes. By doing so, we can ensure a smooth transition and create a sustainable and inclusive future for all.

6. CONCLUSION

The potential of transport innovation to augment the workforce is quite significant. The primary objective of this research was to examine the impact of two often-seen transit phenomena, namely network expansion and automation, on driver resources. The West Midlands area was chosen as a case study for the purpose of this research.

The use of a mixed-methods methodology, including the integration of case study analysis, forecasting, and literature review, resulted in the acquisition of diagnostic, predictive, and prescriptive insights about the efficient administration of change. The research revealed the need for progressively integrating automated integration throughout the process of growth. It was shown that the duties associated with driving will gradually decrease.

The primary implications of this research include the incorporation of analytics into the decision-making process, namely within the domain of planning, and the formulation of workforce policies that are congruent with projected shifts in job roles. Nevertheless, it is important to underscore that the workforce needs to retain its central position in the realm of innovation. The manifestation of development should be consistent with the group's common objectives.

In recent times, the railway sector has seen the initiation of several educational and workforce development initiatives through a range of European Union (EU) and international programmes. Within the domain of European transport projects, it is crucial to recognise the presence of many notable undertakings. Among the several projects mentioned, namely "ASTONRail project (funded by ERASMUS+) [28], STAFFER project (funded by ERASMUS+) [29], EURNEX [30], SKILLRAIL [31], and SKILLFUL [32]", it is noteworthy to highlight their significance as notable endeavours. These efforts are primarily focused on enhancing the worldwide capabilities needed to efficiently handle the many disruptions that have arisen as a result of advancements in the sector.

Transport authorities need to proactively foster widespread innovation that yields societal advantages at large. The enhancement of worker empowerment plays a pivotal role in exerting influence and fostering transformative processes within organisational contexts. In addition, it is crucial for communities to actively engage in the process of providing their own ideas and opinions. Urban regions have the capacity to successfully amalgamate technological breakthroughs with robust social awareness via the exhibition of confidence, attention, and a collective spirit.

This research signifies a noteworthy achievement in the ongoing effort to provide fair and ethically sound opportunities for mobility in the next few years. Continuous study is required to understand the complex dynamics of transportation. In this particular setting, there is a notable potential for the improvement of the labour force, under the condition that we demonstrate a collective commitment to its joint construction.

REFERENCE

[1] Wishart, J., Como, S., Forgione, U., Weast, J., et.al. Literature review of verification and validation activities of automated driving systems. *SAE Int. Journal of Connected and Automated Vehicles*. 2021; 3: 267-323.

[2] UITP. *World Metro Figures.* 2022. https://www.uitp.org/publications/metro-world-figures-2021/ [Accessed 6th May 2023].

[3] Castells, R. M., Graham, I. R., Andrade, C., Churchill, G., et.al. Automated metro operation: greater capacity and safer, more efficient transport. *PTI*. 2011, 15-21.

[4] PwC. *The Potential Impact of Artificial Intelligence on UK Employment and the Demand for Skills*. 2021. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1023590/impact-of-ai-on-jobs.pdf [Accessed 2nd June 2023].

[5] Railway Technology. *How could rail industry careers change in the future?* 2019. https://www.railway-technology.com/features/railway-jobs-of-the-future/ [Accessed 2nd April 2023].

[6] Weerawat, W., Kirawanich, P., Fraszczyk, A. and Marinov, M. *Urban Rail Transit*. UK: Springer. 2020.

[7] Li, S., Lyu, D., Huang, G., Zhang, X., et al. Spatially varying impacts of built environment factors on rail transit ridership at station level: A case study in Guangzhou, China. *Journal of Transport Geography* 2020. 82, p.102631.

[8] Wu, S.S., Zhuang, Y., Chen, J., Wang, W., et al. Rethinking bus-to-metro accessibility in new town development: Case studies in Shanghai. *Cities*. 2019; 94: pp.211-224.

[9] Gualtieri A, Marinov M. The Metro Network Extension in the West Midlands: A Socio-economic Impact Assessments. In Weerawat W, Kirawanich P, Fraszczyk A, Marinov M, editors, Urban Rail Transit: Proceedings of the 6th Thailand Rail Academic Symposium. 2020. p. 115-137. (Lecture Notes in Mobility). doi: 10.1007/978-981-15-5979-2_6

[10] West Midlands Metro. *Expansion*. https://westmidlandsmetro.com/about/expansion/ [Accessed 7th May 2023].

[11] Thomas, P. The feasibility case for converting existing heavy metro systems to driverless operation. *Computers in railways X*. WIT Press, Ashurst. 2006: pp.363-372.

[12] UITP. *Why choosing metro automation?* https://metroautomation.org/why-choosing-metro-automation/ [Accessed 20th July 2023].

[13] Papadimitriou, E., Schneider, C., Tello, J., Damen, W., et al. Transport safety and human factors in the era of automation: What can transport modes learn from each other? *Accident Analysis & Prevention*. 2020; 144.

[14] Powell, J.P., Fraszczyk, A., Cheong, C.N., Yeung, H.K. *Potential Benefits and Obstacles of Implementing Driverless Train Operation on the Tyne and Wear Metro: A Simulation Exercise*. Urban Rail Transit 2. 2016: 114–127. DOI: https://doi.org/10.1007/s40864-016-0046-9 [Accessed 5th April 2023].

[15] Brandenburger, N. and Naumann, A. On track: a series of research about the effects of increasing railway automation on the train driver. *IFAC-PapersOnLine*. 2019; 52(19): 288-293.

[16] Snell, D. and Gekara, V. Re-examining technology's destruction of blue-collar work. *New Technology, Work and Employment*. 2022. DOI: https://doi.org/10.1111/ntwe.12259 [Accessed 7th May 2023].

[17] Li, L. *Reskilling and upskilling the future-ready workforce for industry 4.0 and beyond*. Springer; 2022: 1-16.

[18] Karvonen, H., Aaltonen, I., Wahlström, M., Salo, L., et al. Hidden roles of the train driver: A challenge for metro automation. *Interacting with computers*. 2011; 23(4): 289-298.

[19] Jansson, E., Olsson, N.O. and Fröidh, O. Challenges of replacing train drivers in driverless and unattended railway mainline systems—A Swedish case study on delay logs descriptions. *Transportation Research Interdisciplinary Perspectives*. 2023; 21, p.100875.

[20] SGTrains. *North-East Line*. https://www.sgtrains.com/network-nel.html [Accessed 1st September 2023].

[21] Alstom. *Transport Project Story*. France. 2023. http://tsdtemp.turnlav.net/cbtc/projects/SIG_Singapore_AutomaticMetro_en.pdf [Accessed 1st September 2023].

[22] ITS International. *Dubai metro - the world's longest automated rail system*. https://www.itsinternational.com/feature/dubai-metro-worlds-longest-automated-rail-system [Accessed 1st September 2023].

[23] Mohan, S. *Dubai Metro Signalling & Train Control System*. https://webinfo.uk/webdocssl/irse-kbase/ref-viewer.aspx?GroupMembers=%7B03+IRSE+Event%7D_&RefNo=1559669757&document=3.07+Mohan+-+Dubai+Metro.PDF&id=84 [Accessed 1st September 2023].

[24] HollySys. 'Hollysys Automation Technologies Enters China's Subway Signaling Market with $48 Million Contract Win', [Press release]. 2009. https://hollysys.investorroom.com/2009-11-09-Hollysys-Automation-Technologies-Enters-Chinas-Subway-Signaling-Market-with-48-Million-Contract-Win?mobile=No [Accessed 1st September 2023].

[25] '6 Key Benefits of Graph Visualizations', *Graphlytic*. https://graphlytic.biz/blog/6-key-benefits-of-graph-visualizations [Accessed 1st September 2023].

[26] Kowieski, J. 'Top seven benefits of data visualization,' *ThoughtSpot*. 2022. https://www.thoughtspot.com/data-trends/data-visualization/benefits-of-data-visualization [Accessed 1st September 2023].

[27] Deloitte. *The Five Benefits of Data Visualization*. https://www2.deloitte.com/nl/nl/pages/tax/articles/bps-the-five-benefits-of-data-visualization.html [Accessed 1st September 2023].

[28] ASTONRail. *Advanced approaches and practices for rail training and education TO innovate Rail study programmes & Improve rail higher education provision*. http://astonrail.eu/dokuwiki/doku.php/start [Accessed 20th June 2023].

[29] STAFFER. https://www.railstaffer.eu/about-staffer/ [Accessed 17th November 2023].

[30] EURNEX. https://www.eurnex.org/ [Accessed 20th June 2023].

[31] SKILLRAIL. *Education and Training Actions for high skilled job opportunities in the railway sector*. https://cordis.europa.eu/docs/results/233/233649/137034131-8_en.zip [Accessed 20th June 2023].

[32] SKILLFUL. *Skills and competences development of future transportation professionals at all levels*. https://skillfulproject.eu/ [Accessed 20th June 2023].